



## THE EFFECT OF FEEDBACK AS SOFT SCAFFOLDING ON ONGOING ASSESSMENT TOWARD THE QUANTUM PHYSICS CONCEPT MASTERY OF THE PROSPECTIVE PHYSICS TEACHERS

Abdurrahman\*<sup>1</sup>, A. Saregar<sup>2</sup>, R. Umam<sup>3</sup>

<sup>1</sup>Graduate Science Education Department, FKIP, University of Lampung Indonesia

<sup>2</sup>Department of Physics Education, Raden Intan State Islamic University of Lampung, Indonesia

<sup>3</sup>Department of Applied Chemistry for Environment, Faculty of Science and Technology, Kwansei Gakuin University, Japan

DOI: 10.15294/jpii.v6i2.7239

Accepted: November 13<sup>th</sup>, 2017. Approved: February 20<sup>th</sup>, 2018. Published: March 19<sup>th</sup>, 2018

### ABSTRACT

Many recent studies have reported that feedback plays a very important role in students' learning outcomes. However, currently, feedback has not been utilized by lecturers and students in the learning process effectively. This study aimed to explore the impact of feedback as a soft scaffolding in the ongoing assessment of Quantum Physics class for the students as prospective Physics teachers. A quasi-experimental design non-equivalent pretest-posttest control group was used to examine the effectiveness of feedback based on ongoing assessment. The results of the study revealed that students who received feedback based on metacognitive and social constructivism on studying Quantum Physics showed better average results compared to students who received traditional feedback based on the cognitivism in the form of correction.

© 2018 Science Education Study Program FMIPA UNNES Semarang

**Keywords:** Feedback, Ongoing assessment, Quantum Physics, Soft Scaffolding

### INTRODUCTION

Quantum physics is a domain that is still usually viewed as a field of science resulting in "cognitive dilemma" which impacts the understanding of physics and its development. Quantum Physics is sometimes deemed as an interesting and challenging topic to study and develop in the field of physics, because Quantum Physics itself is one of the fields of physics that requires mastery of high-level math as a tool to understand it comprehensively (Rusli et al., 2011; Asikainen et al., 2005; Hobson, 1996; Saregar, 2016). One of the high-level math, which is difficult to understand is a random calculation such as the numerical method used to determine the price of an option (Monte Carlo simulation or Ameri-

can put) (Syazali, 2011), the concept of random determination can also be used in the search of the particles in the box that are often discussed in Quantum Physics. Likewise with the concept of "Bilateral Matching with Latin Squares" in determining the diversity of a limited numerical value using a matrix (Syazali, 2008), this concept is also used in quantum physics, especially in finding the probability of a value. Several research results show that Quantum Physics is likely to be an interesting research topic for students. This is quite reasonable because it has been known that the development of modern science and technology today directly related to the development of Quantum Physics. Therefore, the study of Quantum Physics requires a number of innovations, including the simulation of abstract and complicated concepts to be easily understood (Wieman et al., 2008).

\*Correspondence Address:

E-mail: [abdurrahman.1968@fkip.unila.ac.id](mailto:abdurrahman.1968@fkip.unila.ac.id)

(Bao & Redish, 2002), reveals that many physics teachers in high school level possess a very low level of Quantum Physics concepts mastery. Consequently, the learning process of Quantum Physics concepts in high school becomes an unimportant part or even missed, so that the students do not have high interest in studying the concept of Quantum Physics (Aprilyawati & Abdurrahman, 2009). Therefore, for prospective teachers, various strategies and methods of quantum physics learning have been developed in universities by various researchers to improve the achievement of Quantum Physics subjects or modern physics (Hobson, 1996; Mason & Singh, 2010; Wittmann et al., 2006; Zhu & Singh, 2011). Even the use of information technology in the study of Quantum Physics or Modern Physics is currently a new trend in physics learning (Robblee & Abegg, 1999; Wieman et al., 2008; Zollman et al., 2002). The Efforts to improve students' understanding are mostly focused on learning innovations, especially improvements in the syntax or learning phase in addition to media and learning resources. However, the researchers rarely innovate and improve the study of quantum physics in the context of assessment, especially the application of formative assessment (Ongoing assessment) as an alternative to improve learning performance of the students by involving feedback activities effectively in it (Stiggins & DuFour, 2009).

Feedback is one of the continuum factors of learning that has a very strong impact on the success of the learning process and achievement of students (Black & Wiliam, 1998; Hattie & Timperley, 2007). Further, Hatti and Timperley argue that it is basically defined as the consequence of performance, meaning that students can monitor their learning achievements through a number of improvement responses to each "evaluation," either self-assessment, teacher (ongoing and formative assessment), other students (peer-assessment), or parents. Feedback, when viewed from its role attributes can be divided into five categories: correction, reinforcement, forensic diagnostic, benchmarking, and longitudinal development (Price et al., 2010).

Some researchers indicate that feedback is sometimes only a unilateral effort of the teacher without any active involvement from the students in responding and applying it in the subsequent learning (Taras, 2003). Thus, the feedback will not be optimally applied if the students are not actively involved in a series of learning processes. In fact, sometimes students rarely read or respond to feedback given by teachers or lecturers.

This phenomenon happens because they do not understand the purpose and process of feedback, so few of them devote themselves to the feedback process (Duncan, 2007).

The impact of variations in feedback interventions in the learning process has been extensively investigated (Hattie & Timperley, 2007; Shute, 2008), and the results show a number of facts leading to the same conclusion that feedback is instrumental in improving students learning outcomes (Black & Wiliam, 1998; Kluger & DeNisi, 1996; Shute, 2008). Nevertheless, the effectiveness of feedback done in the classroom as a mean of improving process quality and learning achievement is often a factor of dissatisfaction among practitioners in their implementation (Price et al., 2010). One of the factors of dissatisfaction is the low involvement of students in responding to feedback made by teachers or lecturers in the classroom, even though students have the best position to assess the effectiveness of the feedback. This happens because students have no knowledge or literacy about the importance of the role of feedback in the learning process. In this case, a lecturer should provide a number of strategies to perform some scaffolds in feedback activities. Soft scaffolding such as questioning, encouraging, directing, giving guidance in problem-solving and other strategies, is a very important factor in engaging students actively and critically in the learning process (Brush & Saye, 2002; Nyamupangu & Lelliott, 2012; Sousa, 2014).

In addition to the feedback characteristics mentioned previously, there are many variables that contribute to the relationship between feedback and learning outcomes. Stobart (2008) States that there are three conditions that must be fulfilled in order to achieve effective and useful feedbacks in learning: (1) students need feedback, (2) students receive feedback and have time to use it, (3) students are willing to use and able to utilize feedback. The first reason that students need feedback is the gap between the learning objectives and the achievement of the students' learning outcomes (Hattie & Timperley, 2007). The implication is that if there is no gap, such students do not require feedback. Furthermore, Timmers & Veldkamp (2011) state that in the feedback process, not all students show the same enthusiasm when feedback is given. The students' attention is usually focused on correcting errors in an assessment that is incorrectly answered, while very little time is given for feedback on the correct answer.

Another result indicates that the longer the assessment (time and number of questions), the less interesting for the students to respond to the

feedback given by the teacher (Timmers & Veldkamp, 2011). In line with these findings, (Stobart, 2008) claims that the interaction between item difficulty, length of assessment and students' characteristics determine the amount of attention toward the feedback and its effects in the process of achieving the learning objectives. The willingness to use feedback is closely related to learning motivation that allows the students to find and provide learning resources to improve their learning performance (Azevedo & Bernard, 1995; Mory, 2004; Saregar et al., 2017). Contrary, if the feedback refers to the students' inability to acquire learning resources, then they will not be able to utilize the feedback (Stobart, 2008). Furthermore, feedback should be given clearly without any disruption so that it can determine the success of the feedback and sustainability of its application (Mory, 2004).

## METHODS

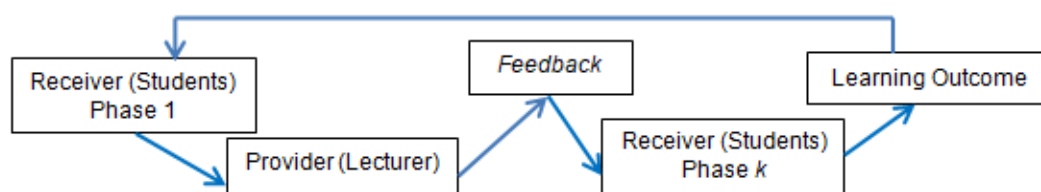
This study used quasi-experimental methods with a non-equivalent quantitative design of pre-post control group design (Creswell, 2013). Data on the mastery of quantum physics concepts was obtained by using the Inventory test of Quantum Physics concepts (IPKFK). A total of 37 students were involved in the study, with 19 students in the experimental class and 18 students in control class. The experimental class was given feedback as soft scaffolding based on social and metacognitive constructivism learning theory in applying ongoing assessment using the flash card, whereas the control group only used regular feedback on formative assessment based on cognitive learning theory. Table 1 below presents the demographics of the research sample.

**Table 1.** The Demographics of the Research Samples and Treatments

Group	Treatment	Frequency Assessment	Number of Students (N)
Experimental	Ongoing assessment with feedback using flash card in combination with correction and reinforcement	3x	19
Control	Formative assessment with feedback through paper-based test with correction	1x	18

Schematically, the process of ongoing assessment and feedback activity in the experimental class using feedback model from metacognitive and social constructivism theory in the form of correction and cyclic Reinforcement can be seen in figure 1. The assessment of ongoing assessment was assisted by flashcards made of 5 x 10 cm cardboard paper with the letters A, B, C, and D. Each student in the experimental class got four flashcards. These cards served as clickers when the lecturer applied the ongoing assessment. While the feedback was given to the class

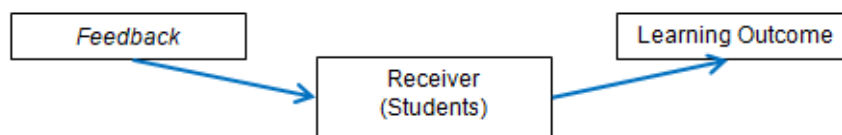
just after the students gave the previous answer by observing and recording the students' answer on ongoing assessment beforehand. This feedback cycle was repeated three times (3x) in each meeting with an aspect-oriented reinforcement to soft scaffolding activities in the form of a dynamic effort by the lecturer in diagnosing and improving the students' response in responding formative assessment results through guidance, motivation, reflection, and peer-collaboration (Xun & Land, 2004).



**Figure 1.** The Model of Metacognitive and Social Constructivism Feedback (Thurlings, et al., 2013)

Students in the control class received direct feedback after formative assessment at each meeting with feedback model based on the cognitive learning theory perspective (figure 2) in the category of correction only. The learning model applied to both groups was the same. The colla-

borative discovery learning model adapted from (Gijlers & de Jong, 2005) with the syntax: (1) orientation; (2) hypothesis submission; (3) Planning an investigation; (4) Implementation Monitoring; (5) interpretation of findings; (6) Evaluation.



**Figure 2.** Cognitivism Feedback Model (Thurlings et al., 2013)

## RESULTS AND DISCUSSION

This research was conducted to see the effectiveness of feedback on ongoing assessment in the context of assessment for learning in improving learning achievement on the Quantum Physics subject of the prospective physics teachers.

Based on the result of t-test toward prior knowledge gained through pre-test score on both groups showed that the prior knowledge of both groups was not significantly different ( $t=1,59$ ;  $sig.=1,22$ ;  $p>0,05$ ). This information pointed out that before the treatment was conducted, the samples possessed similar prior knowledge level (see table 2).

**Table 2.** The Result of T-test of Pre-test

	Group	N	Mean	Standard Deviation	$T_{\text{observe}}$	P
Pre-test	Experimental	18	34,94	3,46	1,59	1,22*
	Control	19	32,81	4,61		

\* $p > 0,05$

After the learning process involving feedback activity on ongoing assessment, the students' learning outcomes were analyzed using covariance analysts (ANCOVA) with pretest scores as covariates and post-test scores as dependent variables (table 3.). The analysis showed that there were significant differences in learning outcomes between the experimental group and the control group ( $F = 5.42$ ,  $sig = 0.026$ ,  $p < 0.05$ ). These re-

sults indicated that students studying quantum physics by applying feedback in ongoing assessment based on social constructivism and metacognitive learning theory in the form of combination between correction and reinforcement show better learning outcomes than students who used feedback in the context of cognitivism learning theory in their learning with only correction feedback.

**Table 3.** Descriptive Data and ANCOVA on Pre-test Score

Group	N	Mean	Standard Deviation	Adjusted mean	Standard error	F	P
Experiment	18	53,89	10,97	51,83	2,16	5,42	0,026**
Control	19	74,78	8,85	75,61	2,05		

\*\* $p < 0,05$

The findings of this study indicate that the feedback process in ongoing assessment with soft scaffolding was able to improve students' learning performance significantly. Ongoing assessment with feedback activity encourages students to be more motivated in solving physics problems systematically and improving cognitive processes,

facilitating information processing, and transforming knowledge presented in the learning process. The students primary concern for feedback is generally on correcting errors in resolving or defining solutions to a given problem. Nevertheless, they were very enthusiastic on the reinforcement feedback.

Some of the feedback utilization made by the majority of students was activeness in finding new learning resources. To ensure the lecturers' feedback, they searched for appropriate online literature through Smartphone. The more frequently given assessment and feedback have been proven to be able to increase the accommodation ability toward new learning resources so that they gain new solutions in overcoming the problems of physics. The impact was that the students began to recognize and apply effective ways to reduce the gap between learning achievement and formulated competencies. This is in line with the meta-theory of cognitivism and social constructivism, that feedback supports and plays a role in familiarizing learners with learning outcomes, recognizing the gap between their true achievement and desired performance, and then attempting to close this gap through feedback responses (Nicol & Macfarlane-Dick, 2006; Pokorny & Pickford, 2010). (Espasa & Meneses, 2010) also revealed that effective feedback should be able to encourage students to gain further information and confidence needed to complete tasks.

In addition, feedback also inspires lecturers to perform a number of sequence improvements (stages) of learning, especially in providing assistance or cognitive scaffolding for students in performing information processing dynamically (Xun & Land, 2004). Optimizing the principle of collaboration in small groups is easier after feedback is received by students (Jayanti et al., 2016; Saregar et al., 2016). Students realize the importance of peer-coaching in understanding abstract quantum concepts by discussing and exploring the academic motivation of the feedback given by lecturers in improving their learning performance. Conditioning this feedback process provides students with opportunities to respond the feedback content and engage in constructive dialogue with lecturers as a provider of the feedback. In other words, feedback will be more effective in the context of collaboration between the lecturers and students and among the students themselves (Auld et al., 2010; Landry et al., 2009; Nicol & Macfarlane-Dick, 2006).

There are a number of rational arguments for why collaboration among learners is very effective in determining the success of inquiry-based learning or discovery along with its assessment. According to socio-constructivist learning theory (Duit & Treagust, 1998) learners' competencies will grow through the process of problem-solving activity done collaboratively among learners. In addition, some studies suggest that one of the obstacles in mastering quantum physics

concepts is the use of high-level mathematics, causing a constraint for students in understanding the lectures in Quantum Physics classes (Singh, 2008; Wuttiptom et al., 2009; Zhu & Singh, 2011). The application of feedback in the form of reinforcement in a logical mathematical explanation along with a number of very contextual physical meanings is a supporting factor for students in improving motivation and creativity in physics problem-solving. This is in line with the theory of social constructivism learning, that the fully rewarded and honest (open) feedback done by lecturers/teachers will imprint on students' memories permanently (Li, Liu, & Steckelberg, 2010) and will encourage positive motivational beliefs in achieving learning objectives (Martens et al., 2010).

In addition, the key to successful feedback by lecturers/teachers as a provider of feedback is to maintain mutual relationships with receivers/students (Pokorny & Pickford, 2010). Besides, the students' learning performance is sustained by frequent feedbacks conducted in the experimental class, which greatly assist the students in improving their thinking skills. The correctness and reinforcement process in the form of soft scaffolding will create students' natural state in thinking activity, and easily accommodate the next information stimulated by the teachers or other learning resources. Orsmond & Merry (2011) revealed that effective feedback should engage students in thinking, so explicit feedback activity will improve alternative strategies for better learning. The content of Quantum Physics seems to be difficult, complicated, and abstract because it uses a high level of mathematical approach that can be overcome by improving analytical thinking skills and strategies scaffolded by the lecturers in the process of physics problem-solving strategy as part of the feedback reinforcement activity based on the students' response toward ongoing assessment issues. This is in line with the results of the study (Fund, 2010; Nahadi et al., 2015) which revealed that students' performance, enthusiasm, and thinking habits in learning heavily depend on the strength of feedback that supports students' involvement in practicing correct thinking strategies in problem-solving.

## CONCLUSION

The potential of formative assessment as an ongoing assessment in the context of assessment for learning is instrumental in encouraging the active involvement of the prospective teachers in the learning process, including a challenging

and abstract subjects such as Quantum Physics. Such active and dynamic involvement relies heavily on content feedback as the core of ongoing assessment. The combination of content feedback between correction that involve students collaboratively and lecturers' reinforcement in the context of soft scaffolding with the help of flashcards greatly determines the level of competency achievement of the prospective teachers as the students in the subjects of Quantum Physics.

Students' interaction through feedback (individual or group correction and reinforcement during ongoing assessment), lecturers, and lecture materials are an integral part in determining the success of the students as prospective teachers in mastering the subjects of Quantum Physics. Some of the difficulties in the use of high-level mathematics to explain quantum phenomena are gradually eliminated during the ongoing assessment cycle process in the context of metacognitive learning theory and social constructivism. The use of tools such as flashcards encourages students to do some self-corrections and prepare physics problem-solving strategies after constructive reinforcements were done by lecturers and peers.

#### ACKNOWLEDGMENT

This research was funded by DIPA Institution Grant of FKIP University of Lampung in 2015. Therefore the researchers would like to thank the chairperson of Faculty of Teacher Training, Lampung University for the opportunity to obtain the research fund. Thank you also to Physics Education Students of FKIP UNILA who were actively involved in this research.

#### REFERENCES

- Aprilyawati, R., & Abdurrahman. (2009). *Pemanfaatan Virtual Laboratory untuk Meningkatkan Minat Siswa SMA pada Topik Fisika Modern* (pp. 92-101). Bandar Lampung: FKIP Universitas Lampung.
- Asikainen, M., Hervonen, P., Heikkinen, M., Nivalainen, V., & Viiri, J. (2005). A Novel Quantum Physics Course for Physics Teachers: Theoretical Background. In Abdurrahman, (2011). *Penggunaan multiple representasi pada penyusunan argumen untuk meningkatkan penguasaan konsep fisika kuantum. Jurnal Penelitian Pendidikan IPA*, 5(1).
- Auld, R. G., Belfiore, P. J., & Scheeler, M. C. (2010). Increasing pre-service teachers' use of differential reinforcement: Effects of performance feedback on consequences for student behavior. *Journal of Behavioral Education*, 19(2), 169-183.
- Azevedo, R., & Bernard, R. M. (1995). A meta-analysis of the effects of feedback in computer-based instruction. *Journal of Educational Computing Research*, 13(2), 111-127.
- Bao, L., & Redish, E. F. (2002). Understanding probabilistic interpretations of physical systems: A prerequisite to learning quantum physics. *American Journal of Physics*, 70(3), 210-217.
- Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: principles, policy & practice*, 5(1), 7-74.
- Brush, T. A., & Saye, J. W. (2002). A summary of research exploring hard and soft scaffolding for teachers and students using a multimedia supported learning environment. *The Journal of Interactive Online Learning*, 1(2), 1-12.
- Creswell, J. W. (1994). *Research design: Qualitative & quantitative approaches*. Sage Publications, Inc.
- Duit, R., & Treagust, D. F. (1998). Learning in science: From behaviourism towards social constructivism and beyond. *International handbook of science education*, 1(1), 3-25.
- Duncan, N. (2007). 'Feed-forward': improving students' use of tutors' comments. *Assessment & Evaluation in Higher Education*, 32(3), 271-283.
- Espasa, A., & Meneses, J. (2010). Analysing feedback processes in an online teaching and learning environment: an exploratory study. *Higher education*, 59(3), 277-292.
- Fund, Z. (2010). Effects of communities of reflecting peers on student-teacher development—including in-depth case studies. *Teachers and Teaching: theory and practice*, 16(6), 679-701.
- Gijlers, H., & De Jong, T. (2005). The relation between prior knowledge and students' collaborative discovery learning processes. *Journal of research in science teaching*, 42(3), 264-282.
- Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of educational research*, 77(1), 81-112.
- Hobson, A. (1996). Teaching quantum theory in the introductory course. *Physics Teacher*, 34, 202-209.
- Jayanti, R. D., Romlah, R., & Saregar, A. (2016). Efektivitas Pembelajaran Fisika Model Problem Based Learning (PBL) melalui Metode POE terhadap Kemampuan Berpikir Tingkat Tinggi Peserta Didik. In *Seminar Nasional Pendidikan* (pp. 208-214).
- Kluger, A. N., & DeNisi, A. (1996). The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological bulletin*, 119(2), 254-284.
- Landry, S. H., Anthony, J. L., Swank, P. R., & Monseque-Bailey, P. (2009). Effectiveness of comprehensive professional development for teachers of at-risk preschoolers. *Journal of Educational Psychology*, 101(2), 448-465.
- Li, L., Liu, X., & Steckelberg, A. L. (2010). Assessor or assessee: How student learning improves by giving and receiving peer feedback. *British Journal of Educational Technology*, 41(3), 525-536.

- Martens, R., De Brabander, C., Rozendaal, J., Boekaerts, M., & Van der Leeden, R. (2010). Inducing mind sets in self-regulated learning with motivational information. *Educational studies*, 36(3), 311-327.
- Mason, A., & Singh, C. (2010). Do Advanced Physics Students Learn From Their Mistakes Without Explicit Intervention? *American Journal of Physics*, 78(7), 760-767.
- Mory, E. H. (2004). Feedback research revisited. *Handbook of research on educational communications and technology*, 2, 745-783.
- Syazali, M. (2008). Pemadanan Bilateral dengan Rancangan Bujursangkar Latin.
- Syazali, M. (2011). Penentuan Harga Opsi Put Amerika dengan Simulasi Monte Carlo.
- Nahadi, N., Firman, H., & Farina, J. (2015). Effect of Feedback in Formative Assessment in the Student Learning Activities on Chemical Course to the Formation of Habits of Mind. *Jurnal Pendidikan IPA Indonesia*, 4(1), 36-42.
- Nicol, D. J., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in higher education*, 31(2), 199-218.
- Nyamupangedengu, E., & Lelliott, A. (2012). An exploration of learners' use of worksheets during a science museum visit. *African Journal of Research in Mathematics, Science and Technology Education*, 16(1), 82-99.
- Orsmond, P., & Merry, S. (2011). Feedback alignment: effective and ineffective links between tutors' and students' understanding of coursework feedback. *Assessment & Evaluation in Higher Education*, 36(2), 125-136.
- Pokorny, H., & Pickford, P. (2010). Complexity, cues and relationships: Student perceptions of feedback. *Active Learning in Higher Education*, 11(1), 21-30.
- Price, M., Handley, K., Millar, J., & O'donovan, B. (2010). Feedback: all that effort, but what is the effect?. *Assessment & Evaluation in Higher Education*, 35(3), 277-289.
- Robblee, K. M., & Gerald Abegg, P. G. (1999, March). Using computer visualization software to teach quantum science: the impact on pedagogical content knowledge. In *Papers presented at the annual meeting National Association for Research in Science Teaching March, 1999* (p. 11).
- Rusli, A., & Waldrip, B. Implementasi Pembelajaran Berbasis Multi Representasi untuk Peningkatan Penguasaan Konsep Fisika Kuantum. *Cakrawala Pendidikan*, (1), 30-45.
- Saregar, A. (2016). Pembelajaran Pengantar Fisika Kuantum dengan Memanfaatkan Media PhET Simulation dan LKM Melalui Pendekatan Saintifik: Dampak pada Minat dan Penguasaan Konsep Mahasiswa. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 5(1), 53-60.
- Saregar, A., Latifah, S., & Sari, M. (2016). Efektivitas Model Pembelajaran CUPS: Dampak terhadap Kemampuan Berpikir Tingkat Tinggi Peserta Didik Madrasah Aliyah Mathla'ul Anwar Gisting Lampung. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 5(2), 233-244.
- Saregar, A., Marlina, A., & Kholid, I. (2017). Efektivitas Model Pembelajaran ARIAS ditinjau dari Sikap Ilmiah: Dampak terhadap Pemahaman Konsep Fluida Statis. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 6(2), 255-263.
- Shute, V. J. (2008). Focus on formative feedback. *Review of educational research*, 78(1), 153-189.
- Singh, C. (2008). Student Understanding of Quantum Mechanics At The Beginning of Graduate Instruction. *American Journal of Physics*, 76(3), 277-287.
- Sousa, C. (2014). History and Nature of Science enriched Problem-Based Learning on the Origins of Biodiversity and of Continents and Oceans. *Multidisciplinary Journal for Education, Social and Technological Sciences*, 1(2), 142-159.
- Stiggins, R., & DuFour, R. (2009). Maximizing the power of formative assessments. *Phi Delta Kappan*, 90(9), 640-644.
- Stobart, G. (2008). *Testing times: The uses and abuses of assessment*. Routledge.
- Taras, M. (2003). To feedback or not to feedback in student self-assessment. *Assessment & Evaluation in Higher Education*, 28(5), 549-565.
- Thurlings, M., Vermeulen, M., Bastiaens, T., & Stijnen, S. (2013). Understanding feedback: A learning theory perspective. *Educational Research Review*, 9, 1-15.
- Timmers, C., & Veldkamp, B. (2011). Attention paid to feedback provided by a computer-based assessment for learning on information literacy. *Computers & Education*, 56(3), 923-930.
- Wieman, C. E., Adams, W. K., & Perkins, K. K. (2008). PhET: Simulations that enhance learning. *Science*, 322(5902), 682-683.
- Wittmann, M. C., Morgan, J. T., & Feeley, R. E. (2006). Laboratory-tutorial activities for teaching probability. *Physical Review Special Topics-Physics Education Research*, 2(2), 020104.
- Wuttiptom, S., Sharma, M. D., Johnston, I. D., Chitaree, R., & Soankwan, C. (2009). Development and use of a conceptual survey in introductory quantum physics. *International Journal of Science Education*, 31(5), 631-654.
- Xun, G. E., & Land, S. M. (2004). A conceptual framework for scaffolding III-structured problem-solving processes using question prompts and peer interactions. *Educational Technology Research and Development*, 52(2), 5-22.
- Zhu, G., & Singh, C. (2011). Improving Students' Understanding of Quantum Mechanics Via the Stern-Gerlach Experiment. *American Journal of Physics*, 79(5), 499-507.
- Zollman, D. A., Rebello, N. S., & Hogg, K. (2002). Quantum mechanics for everyone: Hands-on activities integrated with technology. *American Journal of Physics*, 70(3), 252-259.



## COMPARISON OF MATHEMATICAL REPRESENTATION SKILL AND SCIENCE LEARNING RESULT IN CLASSES WITH PROBLEM-BASED AND DISCOVERY LEARNING MODEL

**C. Ertikanto\*<sup>1</sup>, U. Rosidin<sup>2</sup>, I. W. Distrik<sup>3</sup>,  
Yuberti<sup>4</sup>, T. Rahayu<sup>5</sup>**

<sup>1,2,3</sup>Postgraduate Faculty of Teacher Training and Education Faculty, Lampung University

<sup>4</sup>Faculty of Tarbiyah, UIN Radin Intan Lampung

<sup>5</sup>Faculty of Education, University of Kebangsaan Malaysia

DOI: 10.15294/jpii.v6i2.9512

Accepted: November 19<sup>th</sup>, 2017. Approved: February 22<sup>nd</sup>, 2018. Published: March 19<sup>th</sup>, 2018

### ABSTRACT

The purpose of this research is to know the difference of mathematical representation skill, the result of science learning and its influence on problem-based learning and discovery learning model. The population of this study was 16 students of PGSD FKIP University of Lampung. Among 534 students, there were two experimental classes consisting of 35 students and each was determined through cluster random sampling. The data on mathematical representation skills and learning outcomes of science were obtained through a description test, five questions for assessing mathematical representation skills, and ten questions for assessing science learning outcomes. From the instruments that had been tested to 30 respondents, it was obtained a valid and reliable instrument with a score of 0.505 for mathematical representation skills, and 0.832 for learning outcomes. Furthermore, the data were analyzed by using normality test, homogeneity test, independent sample t-test, correlation test, and simple linear regression test. The results showed that there was no difference in the result of mathematical representation skill and science learning outcomes, between the problem-based learning model and real discovery. But there is a positive and significant linear influence between the mathematical representation skill and the learning outcomes of science, through a problem-based learning model of discovery.

© 2018 Science Education Study Program FMIPA UNNES Semarang

**Keywords:** discovery, problem-based, skill representation.

### INTRODUCTION

Science or Natural Science (IPA) is a complex science and it is closely related to everyday life. Science is a field of study that not only applies formulas, concepts, or principles in solving a problem, but also scientific activities in the learning process. This scientific activity aims to discover the natural phenomena associated with science in a systematic way. Prospective teachers

(Primary School Teacher Education students) are required to be able to conduct scientific activities that can provide solutions to solve a problem encountered related to learning Science.

Science education is expected to be a vehicle for prospective teachers to gain hands-on experience in the process of developing competence and has the prospect of further development in everyday life. Therefore, in order to achieve the educational objectives set by the government, both general and specific goals, teachers (lecturers/teachers) not only teach as they stand in front of the class, but also educate and facilitate

\*Correspondence Address

E-mail: [chandra.ertikanto@fkip.unila.ac.id](mailto:chandra.ertikanto@fkip.unila.ac.id)



in various activities. In addition to educating and guiding the learners to present knowledge and skills, they also guiding in developing all the potential and character that exist in the learners, so that learners have a deep understanding of science concepts, instead of memorizing it.

In fact, theoretical knowledge can last longer and be stored in memory, if it is obtained empirically, not theoretically. This empirical experience can be obtained through a scientific approach (Budiyanto et al., 2016). The scientific approach also involves learners on the observations required for the formulation of hypotheses or data collection. The scientific approach is generally based on the exposure of data obtained by observation or experiment. Pramita & Rochintaniawati (2015) stated that the scientific approach has a learning activity consisting of the main learning experience, namely: observing, asking, gathering information, associating, and communicating. The scientific approach (Hermawan, 2014; Ambarsari, 2016) can also be applied to some supportive learning models, such as problem-based learning model and discovery.

The research result of problem-based learning model proposed by Purnamaningrum, et al (2012) showed that in a class of problem-based learning, teachers' role is different from traditional class. There are 5 steps of problem-based learning, namely: (1) students are given a phenomenon in everyday life to create problems; (2) students define problem-related; (3) students explain the solution to solve problems ; (4) preparation and planning for reporting, and (5) evaluation of students' learning outcomes. These are problem-based learning steps. By using this problem-based learning model, the students are trained to be more active in learning.

The results of the study with the discovery learning model in its application, according to Istiana et al. (2015) and Isnaningsih & Bimo (2013) showed that the active-student learning method development was underlaid by their curiosity and willingness to self-investigate. Teachers in the classroom serve only as a mentor and direct the learning activities in accordance with the purpose. This model is also defined as a learning model that guides learners to participate in conducting scientific activities of discovery, through systematic steps. Starting from the provision of stimulus, problem determination, problem formulation, hypothetical retrieval, data collection, hypothesis testing for the conclusion, resulting in more meaningful learning. In learning activities with various learning models, the main principle is none other than the success obtained from the learning.

Students' learning outcomes with discovery learning model proposed by Widiadnyana, et al (2014) and Putrayasa (2014) had been proven to improve learning outcomes and mathematical representation skills, because students experience learning and find solutions. Likewise, learning outcomes obtained through the problem-based learning model is the result of student learning from the process of understanding and observing the learning activities provided. According to Santyasa (2007), the results of problem-based learning is the pattern of actions, values, understandings, attitudes, appreciation, and mathematical representation skills.

In the learning activities, representations are generally done through various ways of communication, either in conversation, reading, or writing, as mentioned by Suhandi & Wibowo (2012); and Abdurrahman et al. (2008) that the role of representation is very important in processing information. Representation (Sabirin, 2014) is a substitute for the expression shown in searching for solutions to the problem at hand, as a result of the interpretation of his mind. Solving problems with representations can be displayed through images (visual), words (verbal), tables, graphics, or mathematical symbols. Mathematics is unreal, hence to clarify or to declare in solving the problem, representation is very helpful, that is by changing the unreal thoughts into real (Hayati & Fahrurrozi, 2015). Mathematical representation can be used to express, describe, and analyze a problem to find a solution for it. Thus, it helps students to have the ability of reasoning and understanding the concept by extending their way of thinking mathematically (Chusni, 2017).

In fact, the ability of reasoning or understanding of the concept by the learners is still poor. Learners' bad understanding is influenced by the inability of the learners to represent a problem. Representation is one way to communicate an idea to a problem faced. Tsani (2015) and Artha et al. (2014) in his research point out that the use of representations to communicate ideas or mathematical ideas can enhance the understanding of the concept One of the representations that can help in understanding the concept of science is mathematical representation. It is a mathematical ability in representing the mathematical form of verbal, graphics, visual forms into new, varied mathematical forms.

The mathematical ability of a person is influenced by his/her concept mastery, someone who has high mathematical ability will have high understanding of the studied concept of Suhandi & Wibowo (2012); Abdurrahman et al. (2008), in

their research concluded that Students' mathematics mastery supports them to master science subject. Understanding the concept that students have will affect the learning outcomes achieved by these students. This statement is supported by Widianingtyas et al. (2015) and Yusup (2009) in his research stating that "Basically a person who has the high mathematical ability will easily understand concepts and solve calculation problems, and mathematical ability has a significant effect on learning outcomes".

Problem-based and discovery learning models are very important in a learning process. This is supported by Muhamad (2016) and Puspita et al (2014), who stated that problem-based learning model and discovery learning model can improve the students' learning outcomes because the students learn the concepts in meaningful ways by discovering the new concepts. Knowledge was gained through inquiry and discovery learning and it can last longer and have a better effect on knowledge transfer. Inquiry-based and discovery-based learning improve reasoning and thinking ability freely, and they train the skills from students' knowledge to discovery and the students are able to investigate and solve the problems. Learning outcomes are represented by the ability of students in achieving the end result and it can be noticed by how far the students can solve the problem in the learning process.

The purpose of this research is to know the difference between mathematics representation result and science learning result, and its influence on problem-based learning and discovery model.

## METHODS

This research is an experimental study using Cluster Random Sampling technique. The population of research is six students of PGSD FKIP University of Lampung. The sampling procedure was performed by drawing the class to be

selected as the sample in the study (Nazir, 2013). Two classes were taken consisting of 35 students each. The first class was treated using problem-based learning model, while the second was treated using discovery learning model.

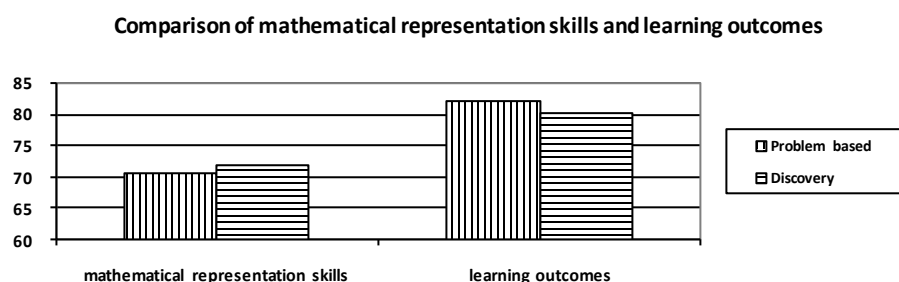
In the learning process, the class with problem-based learning model (Fakhriyah, 2014) adopted learning steps based on problem-based steps on LKS, while the discovery model class adopted learning steps according to discovery steps on LKS.

This research used two descriptive test instruments. The first instrument is five descriptive items, which is used to assess mathematical representation skills, given at the end of each lesson. The second instrument is 10 descriptive items to assess the learning outcomes of Science, given at the end of all material delivery. Data collection was carried out during the learning process. In the implementation, the problem-based class and discovery class are given the same materials, and the learning process is in accordance with the used learning model. Data analysis techniques used were normality test, homogeneity test, Independent Sample T-test, correlation test, and simple linear regression test.

## RESULTS AND DISCUSSION

The results of research are in the form of science learning outcomes and mathematical representation skills. In problem-based learning class, it was obtained that the average score of students' science learning outcomes was 82.11 and mathematical representation skill was 70.57. Meanwhile, in discovery learning class, it was obtained the students' science learning outcomes with the average of 80.11., and the average of mathematical representation skill is 71,71.

The average difference of science learning outcomes and mathematical representation skills in both classrooms is presented in figure 1.



**Figure 1.** Achievements of Learning Outcomes and Mathematical Representation Skills

In Figure 1, it is seen that the results for mathematical representation skills with the problem-based learning model are relatively lower than the discovery learning model, and the learning outcomes of science with the problem-based learning model are relatively higher. The results of the science learning are slightly different due to different learning model factors. It further led to the different average of learning outcomes of science because in discovery learning model learners do relatively little inquiry activity on learning than in the problem-based model. However, both models of learning, there seems to have the same learning activities namely, group work, discussion, and experimenting.

In learning activities of the two experimental classes, learners more frequently learn in groups, discussion activities, experimenting, and discussing the results in groups. They occasionally discuss the problems with the teacher whose function serves as a facilitator. In group learning activities, there are several factors that influence learning, for example, there is a learner who does

not contribute in the group, he/she just relies on his/her friends' help. Furthermore, to find out the comparison of mathematical representation skill, the result of science learning and its effect between the problem-based learning model with the discovery learning are then tested using Independent sample t-Test and regression test.

To test the data distribution whether it is normal or homogeneous, data normality and homogeneity test were conducted. According to Haryati (2012) and Sugiyono (2010), the sample size is relatively large where the sample size  $\geq 30$ , then the distribution of the value differentiation from the data will be close to the normal distribution. In this study, the total number of samples used is 70 students with 35 students with problem-based learning model and 35 students with discovery learning model, so it can be said that the sample of research is normally distributed. To test the data distribution whether it is normal or homogeneous, data normality and homogeneity test were conducted. The test results are listed in table 1 below:

**Table 1.** Sig Value and Decision Making Normality Tests for the Independent Sample T-test

Variable	Sig. Value	Test Criteria	Test Decision
Skill of mathematical representation	0,062	Sig Value $\geq 0,05$	Normal
Learning Outcomes	0,075	Sig Value $\geq 0,05$	Normal

In table 1, it can be seen that the sig value in each sig  $\geq 0.05$  for mathematical representation skill and learning result of learning of lear-

ner. Based on the decision-making criteria, it is concluded that the population is normally distributed.

**Table 2.** Sig Value Based on Mean and Decision Making Homogeneity Test of Science Learning Result and Mathematical Representation Skill for Independent Sample T-test

Variable	Sig. Value	Test Criteria	Test Decision
Skill of mathematical representation	0,402	Sig Value $\geq 0,05$	Homogeneous
Learning Outcomes	0,941	Sig Value $\geq 0,05$	Homogeneous

In table 2, it is seen that the sig Value  $\geq 0.05$  for each. Based on the decision criteria, it is concluded that the sample data is homogeneous. After the data were concluded normal and homogeneous, the Independent Sample t-Test was con-

ducted by testing the variant on Sig Levene's Test for Equality of Variances to see if there are differences in learning outcomes and mathematical representation skills in learning SD Science with discovery and problem-based learning models.

**Table 3.** Test Result Independent Sample T-test

Variable	Sig. Value (2-tailed)	Test Criteria	Making Decision
Skill of mathematical representation	0,705	Sig Value (2-tailed) $\geq$ 0,05	There is no difference
Learning Outcomes	0,627	Sig Value (2-tailed) $\geq$ 0,05	There is no difference

In table 3, the results of the Independent Sample t-Test, Sig. (2-tailed)  $\geq$  0.05, this means that the  $H_0$  is accepted for the learning result hypothesis and the mathematical representation

skill, or there is no difference between the learning result and the mathematical representation skill in the problem-based learning and discovery model.

**Table 4.** Correlation Test Results

Data	r count (Pearson Correlation)	Sig. (2-tailed)	R Square
Skill of mathematical representation -Learning Outcomes (Problem Based Learning)	0,661	0,00	0,436
Skill of mathematical representation -Learning Outcomes (Discovery learning)	0,638	0,00	0,407

Table 4 describes the correlation of the test results. It can be stated that between the mathematical representation skill and the students' learning outcomes, there is a linear correlation. The relationship level of both variables shows that the value of Pearson correlation is 0.661 and 0.638,

meaning that have a strong and positive relationship, R Square value 0.436 and 0.407, which means that learning outcomes are influenced by the skill of mathematical representation with positive regression coefficient.

**Table 5.** Simple Linear Regression Test Result

Learning Outcomes	t-count	Sig.	Remark
Constants	46,630	6,539	0,000
SRM	0,495	5,056	0,000
Constants	45,771	5,907	0,000
SRM	0,519	4,758	0,000

Table 5, explains the result of data analysis at PBL with simple linear regression test that obtained the t-arithmetic for coefficient a of 6,539, bigger than t-table that is 0,36 with Sig value of  $0.000 < 0,05$ . Thus,  $H_0$  is rejected and coefficient a significant. While in the DL with a simple linear regression test that obtained t-count for the coefficient b of (5,056) bigger than t-table that is (0,36) with value of Sig.  $(0.000) < (0,05)$ , so  $H_0$  is rejected and coefficient b significant, hence it can be said that there is significant linear influence and positive influence of mathematical representation skill to result of learning.

The normality test in table 1 and the homogeneity test in table 2 are conducted in several ways i.e. independent sample t-test, correlation test, and simple linear regression test. Based on the test results of Independent sample t-Test in table 3. Apparently, there is no difference in learning outcomes and mathematical representation skill between problem-based learning model with discovery learning model, it means that both learning models have their respective advantages which mutually strengthen the learning activities. Based on figure 1, the results of the analysis show that, the average value of mathematical represen-

tation skills in the discovery learning model is relatively higher compared to the problem-based learning model, while for the average value of learning outcomes in the classroom of learning-based model is relatively higher compared to the discovery learning model class to find out why it can happen and then the assessment can be done as follows.

The average score of science learning outcomes obtained in both experimental classes, after the implementation of the problem-based learning model and discovery learning model, suggest that the material in the problem-based learning model is more easily understood and gives higher learning outcomes because the learning model gives problem closely related problem to everyday life. As the problems are given in the form of LKS, learners are more challenged in finding solutions so that they feel easy to find problems in their daily lives.

The average learning outcomes of the problem-based learning model are relatively higher than in the discovery learning model. The difference in mean scores of learning outcomes in these two small experimental classes may be related to the learning activities of the two classes, both of which have the characteristics of scientific learning: observing, asking, trying, reasoning and communicating (Hermawan, 2014; Ambarsari, 2016), so both models of learning equally provide reinforcement to learning outcomes. Therefore, both learning models are also recommended for learning in primary education (Ertikanto et al., 2017).

Table 4 and table 5 describe the learning activity of the problem based class model which gives a significant and positive linear influence between the mathematical representation skill and the learning outcomes of science with the contribution of 43.60% with the regression equation is  $Y = 46.63 + 0.49X$ , one score of mathematical representation skill of student can increase score result of student learning equal to 0,49, with  $r$  value equal to 0,661 indicates that both variables have strong relation with linear positive direction. That is, the higher the skill of mathematical representation by using the problem-based learning model, the higher the learning result of science. The  $r^2$  value of 0.436 indicates that the mathematical representation skill of the students contributes solely to the students' learning result of 43.60%, while the rest of 56.40% is caused by other variables that are not examined.

This is in line with The previous research done by Tsani (2015) and Artha et al. (2014) suggesting that problem-based learning approaches are richer with representation, and can increase students' motivation in solving problems, generating conceptual knowledge well, and confidence in mastering concepts

The discovery learning model class gives a positive linear influence (Muhamad, 2016; Puspita et al., 2013) and it is also significant between mathematical representation skill and science learning outcomes with contribution of 40.70% with the regression equation is  $Y = 45,77 + 0,51X$ , where the increase of one skill score of mathematical representation of student can increase score of student learning result equal to 0,51, with  $r$  value equal to 0,638, this indicates that both variables have strong relation with positive linear direction.  $R^2$  value of 0.407 indicates that the mathematical representation skill contributes solely to the learning result of 40.70%, while the rest of 59.30% is caused by other variables not examined. This is consistent with previous research that discovery learning model can train students' ability in representing a problem, especially the ability of mathematical representation, as revealed by Muhamad (2013) and Aprilia & Mulyaningsih (2014) that the ability and improvement of mathematical representation and self-learning students with discovery learning model is better than students who received conventional learning.

Table 5 explains that the problem-based learning model has a positive effect on learning outcomes and it has a significant influence on the mathematical representation skill on learning outcomes. It is in line with Fakhriyah (2015) and Purnamaningrum et.al. (2012). The application of problem-based learning generates creativity, and critical thinking to the problem, and better instructional implementation. The students are more flexible in the delivery of ideas and opinions, and learners enjoy working in group work. Chusni (2017) states that basically, someone who has the mathematical ability will easily understand concepts and the can solve the problems of calculation and mathematical items. It is also in line with Widianingtiyas et al. (2015) and Yusup (2009). The concept of learning explains that if students are able to construct and build their own knowledge through the learning process, the knowledge that students have becomes more memorable in the longer term.

## CONCLUSION

Based on the results of research and discussion, it can be concluded that: (1) statistically, there is no difference in the average of science learning outcomes between the problem-based learning class and discovery learning class; and (2) there is difference of influence of student's mathematical representation skill to result of learning between problem based model with discovery.

## REFERENCES

- Abdurrahman., Liliasari., Rusli, A., & Waldrib, B. (2008). Implementasi Pembelajaran Berbasis Multirepresentasi untuk Peningkatan Penguasaan Konsep Fisika Kuantum. *Jurnal Pendidikan Cakrawala*, 30(1), 30-45.
- Ambarsari, D. (2016). Implementasi Pendekatan Saintifik untuk Meningkatkan Keterampilan Mengkomunikasikan dan Prestasi Belajar IPA Siswa Kelas IV SD. *Jurnal Pendidikan Guru Sekolah Dasar*, 5(1), 112-121.
- Aprilia, L., & Mulyaningsih, S. (2014). Penerapan Perangkat Pembelajaran Materi Kalor melalui Pendekatan Saintifik dengan Model Pembelajaran Discovery Kelas X SMA. *Jurnal inovasi Pendidikan Fisika*, 3(03), 1-5.
- Artha, R. A., Bharata, H., & Caswita. (2014). Penerapan Model Pembelajaran Berbasis Masalah untuk Meningkatkan Kemampuan Representasi Matematis Siswa. *Jurnal Pendidikan Matematika*, 2(4), 1-10.
- Budiyanto, M. A. K., Waluyo, L., & Mokhtar, A. (2016). Implementasi Pendekatan Saintifik dalam Pembelajaran di Pendidikan Dasar di Malang. *Proceeding Biology Education Conference*, ISSN: 2528-5742, 13(1), 46-51.
- Chusni, M. M. (2017). Pengaruh Kemampuan Dasar Matematika dan Kemampuan Penalaran Terhadap Hasil Belajar IPA/Fisika pada Peserta Didik Kelas VII SMP Muhammadiyah Muntilan, Kabupaten Magelang, Jawa Tengah. *Berka-la Fisika Indoneia*, 9(1), 16-23.
- Ertikanto, C., Herpratiwi., Yunarti, T., & Saputra, A. (2017). Development and Evaluation of a Model-Supported Scientific Inquiry Training Program for Elementary Teachers in Indonesia. *International Journal of Instruction*, 10(3), 93-108.
- Ertikanto, C., Wahyudi, I., & Viyanti. (2015). Improvement of Teacher Inquiry Capacity Through Teacher Training Program Based on Inquiry and Science Teaching. *Jurnal Pendidikan IPA Indonesia*, 4(2), 142-148.
- Fakhriyah, F. (2014). Penerapan Problem Based Learning dalam Upaya Mengembangkan Kemampuan Berpikir Kritis Mahasiswa. *Jurnal Pendidikan IPA Indonesia*. 3(1), 95-101.
- Haryati, S. (2012). Research And Development (R&D) sebagai Salah Satu Model Pendidikan. *Research and Development*, 37(1), 11-26.
- Hayati, N. & Fahrurrozi. (2015). Pengembangan Perangkat Pembelajaran Berbasis Masalah untuk Meningkatkan Kemampuan Berpikir Kritis dan Komunikasi Matematis, *Jurnal Educatio*, 10(2), 382-399.
- Hermawan, A. A. (2014). Pengembangan Perangkat Pembelajaran Kurikulum 2013 melalui Pendekatan Scientific pada Materi Alat Optik untuk Melatih Sikap Ilmiah Siswa Kelas X SMAN 3 Surabaya. *Jurnal Inovasi Pendidikan Fisika*. 3(3), 96-102.
- Isnainingsih, & Bimo, D. S. (2013). Penerapan Lembar Kegiatan Siswa (LKS) Discovery Berorientasi Keterampilan Proses Sains untuk Meningkatkan Hasil Belajar IPA. *Jurnal Pendidikan IPA Indonesia*, 2(2), 136-141.
- Istiana, G. A., Catur S. A. N., & Sukardjo, J. S. (2015). Penerapan Model Pembelajaran Discovery Learning untuk Meningkatkan Aktivitas dan Penyangga pada Siswa Kelas XI IPA Semester II SMA Negeri 1 Ngemplak Tahun Pelajaran 2013 / 2014. *Jurnal Pendidikan Kimia*, 4(2), 65-73.
- Muhamad, N. (2016). Pengaruh Model Discovery Learning untuk Meningkatkan Representasi Matematis dan Percaya Diri Siswa. *Jurnal Pendidikan Universitas Garut*, 9(1), 9-22.
- Nazir, Moh. 2013. *Metode Penelitian*. Jakarta: Ghalia Indonesia.
- Pramita S.D., & Rochintaniawati, D. (2015). Implementasi Pendekatan Saintifik Terhadap Proses Aktivitas Guru dan Siswa pada Pembelajaran IPA Terpadu. *Prosiding Simposium Nasional Inovasi dan Pembelajaran Sains di ITB*. ISBN: 978-602-19655-8-0.(489-492).
- Purnamaningrum, A., Dwiastuti, S., Probosari, R. M., & Noviwati. (2012). Peningkatan Kemampuan Berpikir Kreatif melalui Problem Based Learning (PBL) pada Pembelajaran Biologi Siswa Kelas X-10 SMA Negeri 3 Surakarta Tahun Pelajaran 2011/2012. *Jurnal Pendidikan Biologi*, 4(3), 39-51.
- Puspita, S.A.R., Pitadjeng., & Nugraheni, N. (2013). Peningkatan Kualitas Pembelajaran Geometri Berbasis Discovery Learning melalui Model Think Pair Share. *Joyful Learning Journal*, 2(3), 1-9.
- Putrayasa, I. M., Syahrudin, H., & Margunayasa. I. G. (2014). Pengaruh Model Pembelajaran Discovery Learning dan Minat Belajar Terhadap Hasil Belajar IPA Siswa. *Jurnal Mimbar PGSD Universitas Pendidikan Ganesha*, 2(1), 1-11.
- Sabirin, M. (2014). Representasi dalam Pembelajaran Fisika. *Jurnal Pendidikan Matematika IAIN Antasari*, 1(2), 33-44.
- Santyasa, I. W. (2007). Model-Model Pembelajaran Inovatif, *Makalah*. 1-16. Disajikan dalam pelatihan tentang Penelitian Tindakan Kelas bagi Guru-Guru SMP dan SMA di Nusa Penida,

- tanggal 29 Juni s.d 1 Juli 2007.
- Sugiyono. (2008). *Metode Penelitian Pendidikan Pendekatan Kuantitatif, Kualitatif, dan (R&D)*. Bandung: Alfabeta.
- Suhandi, A., & Wibowo, F. C. (2012). Pendekatan Multirepresentasi dalam Pembelajaran Usaha-Energi dan Dampak Terhadap Pemahaman Konsep Mahasiswa. *Jurnal Pendidikan Fisika Indonesia*, 8(1), 1–7.
- Tsani, A. M. (2015). Penerapan Model Pembelajaran Berbasis Masalah Untuk Meningkatkan Kemampuan Komunikasi Dan Representasi Matematis Siswa. *Seminar Nasional Matematika Dan Pendidikan Matematika, UNY, ISBN. 978-602-73403-0-5, 99–104*.
- Widiadnyana, I. W., Sadia, I. W., & Suastra, I. W. (2014). Pengaruh Model Discovery Learning Terhadap Pemahaman Konsep IPA dan Sikap Ilmiah Siswa SMP. *e-Journal Program Pascasarjana Universitas Pendidikan Ganesha*, 4(2), 1-13.
- Widianingtyas, L., Siswoyo., & Bakri, F. (2015). Pengaruh Pendekatan Multi Representasi dalam Pembelajaran Fisika Terhadap Kemampuan Kognitif Siswa SMA. *Jurnal Penelitian Pengembangan Pendidikan Fisika*, 1(1), 31-38.
- Yusup, M. (2009). Multirepresentasi dalam Pembelajaran Fisika. *Seminar Nasional Pendidikan FKIP Universitas Sriwijaya*, 1(1), 21-32.



## A ROBUST DATA ENVELOPMENT ANALYSIS FOR EVALUATING TECHNICAL EFFICIENCY OF INDONESIAN HIGH SCHOOLS

U. Mahmudah<sup>\*1</sup>, Suhartono<sup>2</sup>, A.D. Rohayana<sup>3</sup>

<sup>1</sup>Faculty of Tarbiya and Teaching Sciences  
State Islamic Institute of Pekalongan, Pekalongan, Indonesia

<sup>1</sup>School of informatics and Applied Mathematics  
Universiti Malaysia Terengganu, Malaysia

<sup>2</sup>Sebelas Maret University, Kebumen, Indonesia

<sup>3</sup>State Islamic Institute of Pekalongan, Pekalongan, Indonesia

DOI: 10.15294/jpii.v7i1.9883

Accepted: November 30<sup>th</sup>, 2017. Approved: February 28<sup>th</sup>, 2018. Published: March 19<sup>th</sup>, 2018

### ABSTRACT

The main purpose of this study is to evaluate the technical efficiency of high school education in Indonesia by applying Data Envelopment Analysis (DEA), which is the most frequently used to measure the efficiency scores. However, this study uses a robust approach to face the complex problem of the traditional DEA, which may lead to biased results. Besides, it is a powerful approach to estimate technical efficiency when outliers contaminate the data set. Statistical data from general senior secondary schools in the period 2015/2016 is analyzed, using 34 provinces as decision-making units (DMUs), with eight input and six output variables. The results indicate that the average efficiency score of Indonesia's major political subdivisions in managing high school education is 0.936. Furthermore, as many as 32.35 percents of provinces achieve efficient performances, with an efficiency score equal to one, while 17 provinces have above average efficiency scores. The results also indicate that efficiency scores from robust data envelopment analysis provide better accuracy. Overall, application of robust data envelopment analysis (RDEA) is appropriate for measuring the efficiency of provincial performance in organizing secondary education.

© 2018 Science Education Study Program FMIPA UNNES Semarang

**Keywords:** DEA, efficiency, robust, outliers

### INTRODUCTION

High schools are very important educational institutions because they prepare students to face the real world by providing them with the necessary skills and knowledge to be able to live independently and co-exist in the community in a proper manner. Completing the high school level of education may help students in the next stage of their lives, whether they decide to go to college or take the first steps in their careers. Moreover,

it is difficult to find a decent job without a high school diploma, as educational attainment is usually considered to be an absolute requirement in securing a job. In Indonesia, education level is an important consideration in certain positions that require appropriate skills. Therefore, graduation from high school is generally regarded as a minimum requirement for further education or for direct entry into work.

Therefore, analysis of the measurement of the efficiency of high school education is important. This study aims to measure the efficiency of Indonesia's major political subdivisions in orga-

\*Correspondence Address:  
E-mail: u\_mudah@yahoo.com



nizing high school education by using the DEA method. However, a robust approach is used to face the possibility of the existence of outliers in the actual data set. This approach tends to provide results with better accuracy. By knowing the efficiency of each province in managing high school education, the Indonesian government is consequently able to determine the best role model of high school management in order to improve the efficiency level of other provinces. This study is expected to make a contribution to Indonesian education, especially high school education, and enhance the quality of high school graduates who are ready to meet further challenges, whether these be college life or going straight to work.

Unfortunately, research on high school efficiency measurement in Indonesia is limited. In fact, no research has been found regarding the same topics. Fatimah & Mahmudah (2017) investigate the measurement of the efficiency of elementary schools in Indonesia by using two-stage data envelopment analysis. However, other studies use high schools in Indonesia as samples for evaluation analysis. Yusrizal et al. (2017) investigate the level of knowledge and understanding of physics teachers in Senior High Schools in Banda Aceh when developing and analyzing test items. By using as many as 32 physics teachers, analysis of the results indicates that their skills are not satisfactory.

Measurement efficiency was introduced by Farrel (1957), and one of the most commonly used methods is DEA, which is a non-parametric method for performing frontier analysis to estimate the efficiency scores of DMUs. This method allows us to make comparisons between DMUs in order to establish which are performing efficiently. An efficient DMU has an efficiency score exactly equal to one, which is equivalent to an efficiency value of 100 percent. Otherwise, DMU is said to be inefficient.

Many studies have applied DEA methods to evaluate the efficiency of educational institutions (see, amongst others: Carrington et al., 2005; Kong & Fu, 2012; Nazarko & Saparauskas, 2014; and Mikusova, 2015). Barrow (1991) applied stochastic frontier analysis for estimating the stochastic cost frontier of schools in England, while Bonesrqnning & Rattsq (1994) analyze the efficiency of high schools in Norway. Moreover, the technical efficiency of school districts in South Carolina is studied by Cooper & Cohn (1997). Although the DEA method has notable strengths in the analysis of frontier production, its estimator has complex and multidimensional properties.

Therefore, the existence of outliers causes the traditional DEA method to be sensitive due to it relies on the best DMU. It is important to note that the presence of outliers may produce less accurate results of the analysis. In order to deal with the problem that appears in the traditional DEA, Cooper et al. (1998) and Gstach (1998) use stochastic DEA but this approach usually needs classical assumptions of statistical distribution. Further, Wilson (1995) suggests an approach to detect outliers regarding DEA methods. Other studies which used this procedure are those of Charnes et al. (1992) & Zhu (1996). Furthermore, Bertsimas & Sim (2003) analyze DEA method using robust optimization. However, this study applies robust approach for estimating bias-corrected scores of technical efficiency, which is introduced by Simar & Wilson (1998). The statistical data of Indonesian high schools from 2015/2016 is analyzed using an R program. Due to the importance of science and technology, which influences very many areas, this study focuses on the field of scientific study in high schools in Indonesia. As mentioned by Dwianto et al. (2017), students in Indonesia are left behind regarding science accomplishment and there are some weaknesses in the science learning process.

## METHODS

DEA is a non-parametric method used to measure DMUs by comparing those that have similar characteristics or are homogeneous, based on several input variables, to produce a number of outputs. This method has good advantages compared to other measurement methods because there is no need to make distribution assumptions, which are required in a parametric analysis. DEA method consists of two models, i.e. the CRS (constant return to scale) and the VRS (variable return to scale) models. CRS model was introduced by Charnes, et al. (1978), that is why this model is often called the CCR model whereas the second model was developed by Banker, et al. (1984) and also known as the BCC model. However, the second model is a development of the first model. The difference between these two models relies on the initial assumption where the first model uses similarity ratios between the increasing input and output variables. Further, the CRS model also presumes that most DMUs perform at an optimal scale. Meanwhile, the VRS model does not use similarity ratios but the increases in input and output variables are different. Further, the VRS model presumes that DMUs do not perform at an optimal scale.

Basically, the DEA method which is concerning naïve score can be explained as follows. Let the observed input variables are defined by  $x_n$ , where  $n = 1,2,3, \dots, N$  while the output variables are defined by  $y_m$ , where  $m = 1,2,3, \dots, M$ . Suppose that  $P = \{(x, y): x \geq X\beta, y \leq Y\beta, \beta \geq 0\}$ . Therefore, the input set  $Q(y)$  have input variables to produce output variables under  $P$  and condition  $Q(y) = \{(x): (x, y) \in Q\}$  is applied (Shephard, 1981) and Coelli, et al., 1994). Therefore, following Besstremyannaya, et al., (2015) the CRS model of DEA method where input-oriented is applied  $\theta_k$  for  $DMU_k$  where  $k = 1,2,3, \dots, K$  can be written as follows:

$$\min_{\theta_k, \beta} \theta_k \tag{1}$$

subject to

$$\begin{aligned} -y_{mk} + \sum_{k=1}^K \beta_k y_{mk} &\geq 0 \\ \theta_k x_{nk} - \sum_{k=1}^K \beta_k x_{nk} &\geq 0 \end{aligned} \tag{2}$$

and

$$\beta_k \geq 0$$

The assumption used in this model show that has strict convexity as well as disposability of the input and output variables. Strong disposability refers to when  $x \in Q(y)$  and  $x' \geq x$  then  $x' \in Q(y)$ . Further, the additional constraints of  $\sum_{k=1}^K \beta_k x_{nk} = 1$  are needed in order to impose this model on the VRS model.

As this method is based on frontiers, then to produce better results it requires the accuracy and preciseness of the input and output variables, because even the slightest change can change the estimates significantly.

Even though DEA method is very often used and is the most powerful method, precise and accurate data is required to yield unbiased scores of efficiency. However, most researchers face difficulties in obtaining real data accurately because the input and output variables are full of uncertainties. Therefore, in order to deal with the uncertainty this study applies bootstrap method which is a very good method for approximating the estimator where empirical distribution is concerned. Bootstrap is used to correct for bias, as the estimated boundary  $\hat{Q}^a(y)$  of the input

variables may fail to include the most efficient DMU. Consequently, for each DMU  $j$  then bias  $\theta_j$  can be explained by bias  $\bar{\theta}_j = E(\hat{\theta}_j) - \theta_j$ , where it can be written as bias  $\bar{\theta}_j^* = E(\hat{\theta}_j^*) - \hat{\theta}_j$ . Therefore, the following steps are required in fulfilling this:

Step 1: Estimating the naïve scores of DEA in equation (2) that is defined by  $\bar{\theta}_j = (\hat{\theta}_1, \hat{\theta}_2, \dots, \hat{\theta}_I)$

Step 2: Repeating B times to provide bootstrap estimates  $\{\hat{\theta}_{jb}^*\}_b^B$  estimates as many as J sets.

Step 3: Calculating  $\widehat{bias\theta}_j = \frac{1}{B} \sum_{b=1}^B \hat{\theta}_{jb}^* - \hat{\theta}_j$  for  $(x_{jb}^*, y_j)$

Step 4: Calculating bias-corrected efficiency scores by using  $\bar{\theta}_j = \hat{\theta}_j - \widehat{bias\theta}_j$ .

Simar and Wilson (2007) report that the input variables in bootstrap DEA where the input-oriented model is concerned in correcting the bias scores, which is the reciprocal of do not depend on the environmental variables. In other words, the input variables which are not controlled by producers can be explained by the following procedures:

Step 1: Estimating the naïve distance scores which are defined as  $\delta_i$ , where  $i = 1,2,3, \dots, I$ .

Step 2: Assuming that the naïve distance scores  $\delta_i = z_i\gamma + \varepsilon_i \geq 1$ , where  $\varepsilon_i \sim N(0, \sigma_\varepsilon^2)$  with left truncation at  $(1 - z_i\gamma)$ .

Step 3: Calculating  $\hat{\sigma}_\varepsilon$  and  $\hat{\gamma}$  with condition  $\delta_i > 1$ .

Step 4: Repeating B times to provide bootstrap estimates  $\{\hat{\delta}_{ib}^*\}_b^B$  as many as J sets.

Step 5: Calculating  $\widehat{bias\delta}_i = \frac{1}{B} \sum_{b=1}^B \hat{\delta}_{ib}^* - \hat{\delta}_i$ .

Step 6: Calculating bias-corrected scores by using  $\bar{\delta}_i = \hat{\delta}_i - \widehat{bias\delta}_i$ .

## RESULTS AND DISCUSSION

The study uses statistics from high schools from 2015/2016 that were prepared by the Center for Educational and Cultural Data and Statistics, Secretariat General, Ministry of Education and Culture of Republic of Indonesia. Basically, the data presents a general description of high schools in Indonesia that covers the number of schools, applicants, new entrants, students, repeaters, graduates, headmasters, teachers, classes and classrooms. Furthermore, the data is based on the results of the verification and validation that are made by the Secretariat Directorate General of Primary and Secondary Education and

the Directorate of Senior Secondary Schools through basic educational data.

The calculation of efficiency scores using the DEA method is made for all provinces in Indonesia. 34 provinces are used as DMUs, which are analyzed by using six output variables (*O*) and

eight input variables (*I*). Furthermore, the study is based on high schools from a Science point of view, so the output variables are the average of national exams in the Science field of study. Table 1 gives a general description for all the variables used in this study.

**Table 1.** Descriptive Statistics

Var	Min	Max	Mean	Std. Dev
Outputs				
<i>O1</i>	64.54	82.79	73.28	4.98
<i>O2</i>	49.83	85.66	63.20	7.67
<i>O3</i>	32.03	80.74	54.42	11.75
<i>O4</i>	39.39	85.98	61.18	12.61
<i>O5</i>	34.57	82.19	55.62	11.23
<i>O6</i>	40.19	82.72	59.36	9.85
Inputs				
<i>I1</i>	55	1441	373.21	348.14
<i>I2</i>	14,357	577605	126835.5	133009.9
<i>I3</i>	103	13979	2562.79	3417.38
<i>I4</i>	41	1016	277.88	253.76
<i>I5</i>	93	3057	811.35	795.02
<i>I6</i>	4,709	182795	41870.79	43196.72
<i>I7</i>	531	18057	4320.38	4252.57
<i>I8</i>	489	18261	4388.06	4338.48

*I1* indicates the number of schools; *I2* the number of students; *I3* the number of teachers; *I4* the number of libraries; *I5* the number of laboratories; *I6* the number of graduates; *I7* the number of classes; and *I8* the number of classrooms. The output variables are the average of national exams in the Science field of study, namely the

average of the Indonesian language (*O1*); that of the English language (*O2*); the average of mathematics (*O3*); of physics (*O4*), of chemistry (*O5*); and of biology (*O6*). Table 2 shows the cumulative distribution of the efficiency scores for traditional DEA.

**Table 2.** Cumulative Distribution

Scores	Total
1.000	11
0.950-0.999	3
0.900-0.949	12
0.850-0.899	4
0.800-0.849	2
<0.800	2
Total	34

The analysis results indicate that the average of the efficiency scores of Indonesia's major political subdivisions in managing high school

education is 0.936, with a standard deviation of 0.065. Figure 1 indicates the traditional DEA efficiency scores for all provinces in Indonesia.

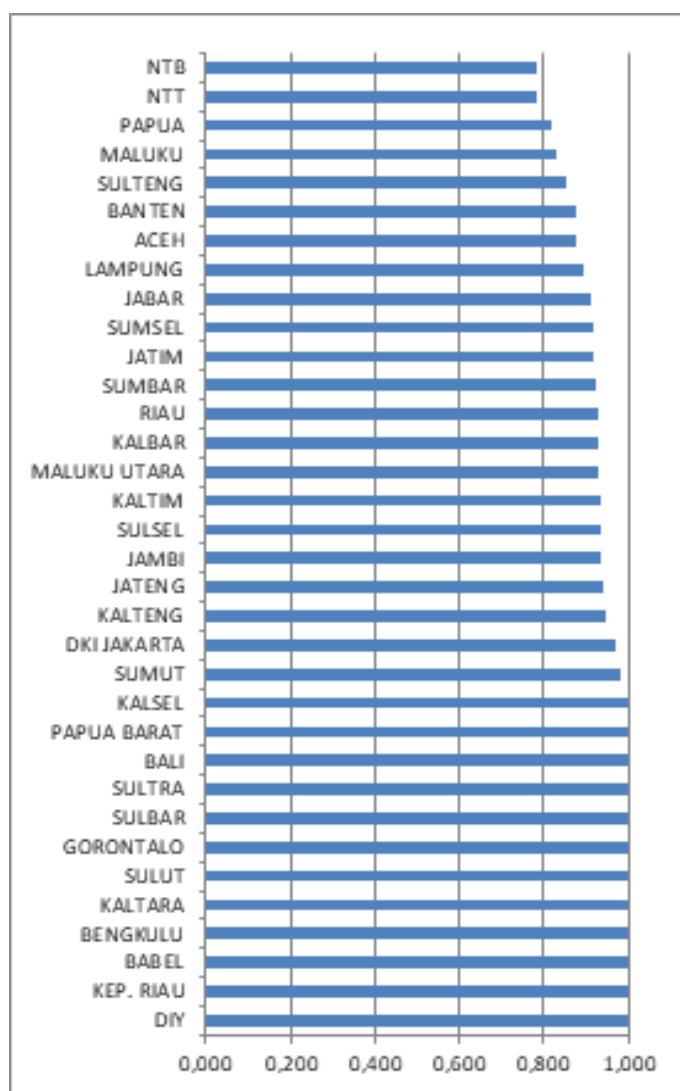


Figure 1. Efficiency Scores

32.35 percent of provinces show an efficient performance, with an efficiency score equal to one. Further, 17 provinces (50 percent) have efficiency scores above the average score. The lowest efficiency score is 0.785, corresponding to West Nusa Tenggara.

Based on discrimination stages introduced by Thanassoulis et al. (1987) then it is save report that the province of South Kalimantan should be able to sustain its activities to produce an optimum output using only 99.9 percent of the available inputs, whereas the province of North Sumatra should be able to carry out its activities with optimum results using 98.5 percent of the existing resources. The Special Capital Region of

Jakarta requires 96.9 percent of the input variables to be able to carry out its activities.

As previously mentioned, traditional DEA tends to provide biased efficiency scores. Besides, the actual data can be contaminated by outliers, which all the input variables contain. This study applies a robust approach of bias-corrected technical efficiency to DEA scores. Figure 2, 3 and 4 show a comparison of the efficiency scores for the 34 provinces in Indonesia using traditional DEA and robust DEA, in which the number of bootstrap replications  $B = 100, 500$  and  $1000$ . Furthermore, this study uses the size of confidence intervals for the bias-corrected DEA scores  $\alpha = 0.01, 0.02$  and  $0.05$ .

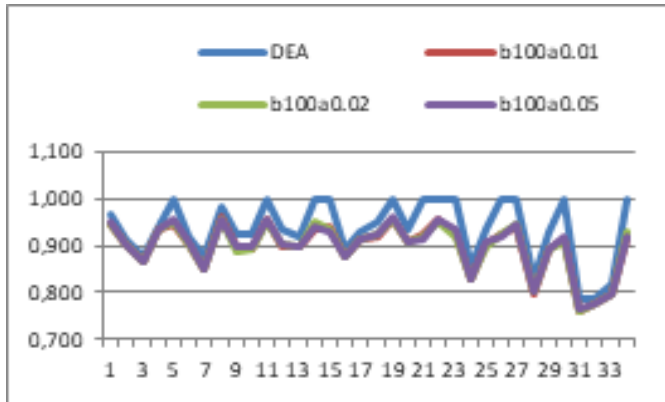


Figure 2. DEA vs RDE (B=100)

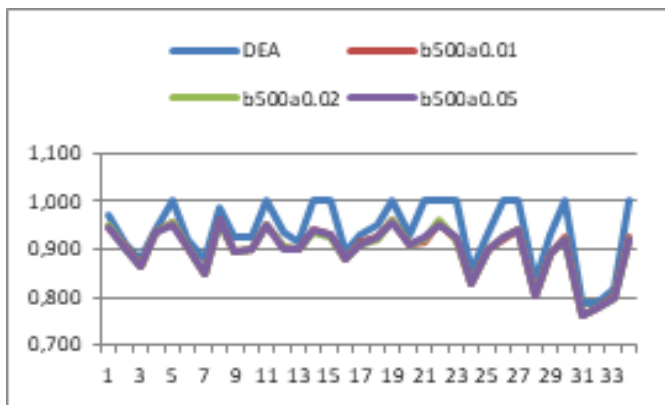


Figure 3. DEA vs RDE (B=500)

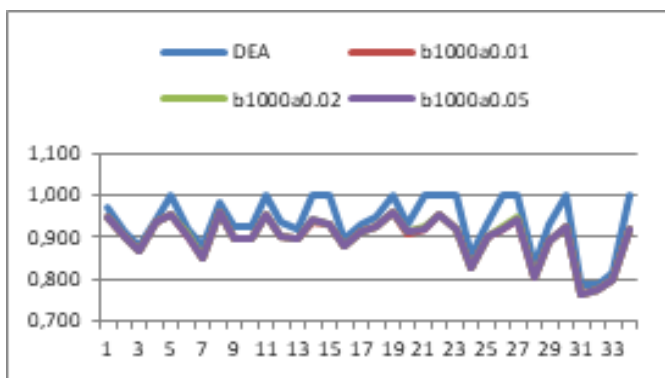


Figure 4. DEA vs RDE (B=1000)

Figure 2, 3 and 4 indicate that the efficiency scores of RDEA deliver consistent results, whose values always follow the technical efficiency scores of traditional DEA. The average of bias for naive DEA scores for all degrees of confidence level ( $\alpha$ ) is classified as small; they have the same bias efficiency score, i.e. 0.04. Descriptive statistics of the RDEA efficiency scores are as follows. The average efficiency scores with replication  $B=100$  and  $\alpha=0.01, 0.02$  and  $0.05$  are (0.898, 0.899, 0.900), while the average efficien-

cy score with replication  $B=500$  and  $\alpha=0.01, 0.02$  and  $0.05$  are (0.900, 0.900, 0.899). The average of efficiency scores with replication  $B=1000$  and  $\alpha=0.01, 0.02$  and  $0.05$  are (0.899, 0.899, 0.900). Further, the standard deviation equals 0.05 for all the replications, as well as for the size of confidence interval. Moreover, the results also indicate that RDEA efficiency scores with number of replications  $B= 100, 500$  and  $1000$  and  $\alpha = 0.01, 0.02$  and  $0.05$  are within the confidence intervals.

## CONCLUSION

This study used robust data envelopment analysis (RDEA) to investigate efficiency measurement when the actual data are contaminated by outliers, as the efficiency scores of traditional DEA are susceptible to bias. 34 provinces were used as DMUs, whose efficiencies were measured by using eight input variables and six output variables to evaluate technical efficiency in managing high school education in Indonesia.

The results show that traditional DEA gives 11 provinces efficiency scores equal to one, which indicates efficient performance. West Nusa Tenggara has the lowest efficiency score (0.785), while fifty percent, or 17 provinces, have efficiency scores above average. The study uses the number of bootstrap replications  $B = 100, 500$  and  $1000$ , while the size of confidence interval  $\alpha = 0.01, 0.02$  and  $0.05$ . The results of RDEA reveal that its efficiency scores always follow the technical efficiency scores of traditional DEA, with its scores within the confidence intervals. Further, the bias efficiency score for all confidence levels is classified as small (0.04). Overall, RDEA is appropriate for application to measure the efficiency of provincial governments in organizing high school education in Indonesia.

## ACKNOWLEDGMENTS

The authors would like to thank the Center for Educational and Cultural Data and Statistics, Secretariat General, Ministry of Education and Culture of The Republic of Indonesia, which has allowed access to data for analysis purposes. The authors would also like to thank the editors for their comments and support during the review process.

## REFERENCES

- Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management science*, *30*(9), 1078-1092.
- Barrow, M. M. (1991). Measuring local education authority performance: a frontier approach. *Economics of Education Review*, *10*(1), 19-27.
- Ben-Tal, A., & Nemirovski, A. (2000). Robust solutions of linear programming problems contaminated with uncertain data. *Mathematical programming*, *88*(3), 411-424.
- Bertsimas, D., & Sim, M. (2003). Robust discrete optimization and network flows. *Mathematical programming*, *98*(1-3), 49-71.
- Besstremyannaya, G., Simm, J., & Golovan, S. (2014). *Robust non-parametric estimation of cost efficiency with an application to banking industry*. Working paper.
- Bonesrønning, H., & Rattsø, J. (1994). Efficiency variation among the Norwegian high schools: consequences of equalization policy. *Economics of education review*, *13*(4), 289-304.
- Carrington, R., Coelli, T. I. M., & Rao, D. S. (2005). The performance of Australian universities: Conceptual issues and preliminary results. *Economic Papers: A journal of applied economics and policy*, *24*(2), 145-163.
- Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European journal of operational research*, *2*(6), 429-444.
- Charnes, A., Haag, S., Jaska, P., & Semple, J. (1992). Sensitivity of efficiency classifications in the additive model of data envelopment analysis. *International Journal of Systems Science*, *23*(5), 789-798.
- Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. Springer Science & Business Media.
- Cooper, S. T., & Cohn, E. (1997). Estimation of a frontier production function for the South Carolina educational process. *Economics of Education Review*, *16*(3), 313-327.
- Cooper, W. W., Huang, Z., Lelas, V., Li, S. X., & Olsen, O. B. (1998). Chance constrained programming formulations for stochastic characterizations of efficiency and dominance in DEA. *Journal of Productivity Analysis*, *9*(1), 53-79.
- Dwianto, A., Wilujeng, I., Prasetyo, Z. K., & Suryadarma, I. G. (2017). The Development of Science Domain Based Learning Tool Which is Integrated with Local Wisdom to Improve Science Process Skill and Scientific Attitude. *Jurnal Pendidikan IPA Indonesia*, *6*(1), 23-31.
- Efron, B. (1979). Bootstrap methods: another look at the jackknife. *Annals of statistics* *7*: 1-26. *View Article PubMed/NCBI Google Scholar*.
- Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society. Series A (General)*, *120*(3), 253-290.
- Fatimah, S., & Mahmudah, U. (2017). Two-Stage Data Envelopment Analysis (DEA) for Measuring the Efficiency of Elementary Schools in Indonesia. *International Journal of Environmental and Science Education*.
- Gstach, D. (1998). Another approach to data envelopment analysis in noisy environments: DEA+. *Journal of Productivity Analysis*, *9*(2), 161-176.
- Kong, W. H., & Fu, T. T. (2012). Assessing the performance of business colleges in Taiwan using data envelopment analysis and student based value-added performance indicators. *Omega*, *40*(5), 541-549.

- Mikušová, P. (2015). An application of DEA methodology in efficiency measurement of the Czech public universities. *Procedia Economics and Finance*, 25, 569-578.
- Ministry of Education and Culture of Republic of Indonesia. 2016. Nilai Rata-rata Sekolah UN. Retrieved from <https://data.go.id/dataset/nilai-rata-rata-sekolah-un>.
- Nazarko, J., & Šaparauskas, J. (2014). Application of DEA method in efficiency evaluation of public higher education institutions. *Technological and Economic development of Economy*, 20(1), 25-44.
- Simar, L., & Wilson, P. W. (1998). Sensitivity analysis of efficiency scores: How to bootstrap in non-parametric frontier models. *Management science*, 44(1), 49-61.
- Simar, L., & Wilson, P. W. (2007). Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of econometrics*, 136(1), 31-64.
- Suhardi, D. (2017). Statistik Persekolahan Sekolah Menengah Atas (SMA) 2016/2017.
- Thanassoulis, E., Dyson, R. G., & Foster, M. J. (1987). Relative efficiency assessments using data envelopment analysis: an application to data on rates departments. *Journal of the Operational Research Society*, 38(5), 397-411.
- Wilson, P. W. (1995). Detecting influential observations in data envelopment analysis. *Journal of productivity analysis*, 6(1), 27-45.
- Yusrizal, Y., Suliyannah, S., & Basri, T. H. (2017). Analysis of Knowledge, Understanding and Skills of Physics Teachers of State Senior High Schools in Developing and Analyzing Test Items. *Jurnal Pendidikan IPA Indonesia*, 6(2), 335-340.
- Zhu, J. (1996). Robustness of the efficient DMUs in data envelopment analysis. *European Journal of operational research*, 90(3), 451-460.



## EFFECTIVENESS OF POGIL WITH SSI CONTEXT ON VOCATIONAL HIGH SCHOOL STUDENTS' CHEMISTRY LEARNING MOTIVATION

I. B. Yuliasitini<sup>\*1</sup>, S. Rahayu<sup>2</sup>, F. Fajaroh<sup>3</sup>, N. Mansour<sup>4</sup>

<sup>1</sup>Public Vocational High School 9, Malang, Indonesia

<sup>2,3</sup>Chemistry Department, Universitas Negeri Malang, Indonesia

<sup>4</sup>Graduate School of Education, University of Exeter, UK

DOI: 10.15294/jpii.v7i1.9928

Accepted: November 4<sup>th</sup>, 2017. Approved: February 21<sup>st</sup>, 2018. Published: March 19<sup>th</sup>, 2018

### ABSTRACT

This study aimed to examine the difference of Vocational High School students' learning motivation after they were taught the topic of the electrolyte solution and redox reaction using POGIL model with SSI context, POGIL, and conventional learning. The research design used was quasi-experiment with the model of pre-test and post-test control group design. The research subjects were three classes with the similar initial ability. The data were obtained using SMTSL motivation questionnaire ( $r = 0.824$ ) and analyzed using ANCOVA. The research results showed a significant difference in learning motivation between students taught using POGIL with SSI context, POGIL, and conventional learning. The students who were taught using POGIL with SSI context had the highest learning motivation compared to those taught using POGIL and conventional learning.

© 2018 Science Education Study Program FMIPA UNNES Semarang

**Keywords:** POGIL, SSI, learning motivation

### INTRODUCTION

Chemistry is one of the subjects taught in Vocational High School (VHS). One of the goals of chemistry learning in VHS which is in accordance with curriculum 2013 stated that the students could understand the concept, principle, law, and theory of chemistry; their connectivity and implementation also can solve the problems in daily life, the technology; and the students have basic competency as the basis for developing the competency in each expertise field. Corresponding to such purposes, the chemistry learning in VHS demands the students' mastery of basic concepts of knowledge in which the process and domain must support the development of skill in fulfillment of the productive expertise program. In the structure of curriculum 2013 for expertise program of technology and engineering in Vocational

High School, chemistry is the part of the subjects of the expertise field basic devotee group (C1). Chemistry is a subject of bonding substance on the basis of expertise field of Technology and Engineering group so that it is very significant for VHS students to understand the topics of chemistry. Moreover, nowadays, chemistry, as the center of science, is one of the sciences underlying the science, technology, and industry (Chang, 2011). Besides, according to Oloruntegbe & Alake (2010), chemistry is a knowledge needed by the students to solve the problems in daily life.

Although the chemistry subject is important, the reality in school shows that most of VHS students dislike the chemistry subject since many of its topics are difficult (Sitepu, 2016; Refriwati, 2015). This case indicates that VHS students' learning motivation is still low. The cause of the low motivation is, for example, generally, the chemistry learning is emphasized on only the con-

\*Correspondence Address:

E-mail: ikaby.smkn9@gmail.com



cept mastery without showing the relationship between concepts learned by implementing them in the daily life (Holbrook, 2005). The lack of information of the relevance of chemistry in the daily life including its relationship with the productive subject is also problematic for students in learning chemistry so that it causes the students' low interest and motivation to study chemistry (Aikenhead, 2003; Price & Hill, 2004). Whereas, there are so many phenomena in the life related to chemistry. For example, in motorcycle automotive engineering, the phenomenon of fuel combustion, corrosion of motorcycle components, work performance of battery/accumulator of the motorcycle, and welding or metal connecting includes chemical reaction.

Another factor that also causes the low motivation of chemistry learning in VHS is the chemistry learning tends to be teacher-centered so far, that is the teacher often employs expository learning model (speech) in which the learning process less includes the students' role; the teacher still dominates the learning process. In expository learning, the teacher transfers the knowledge to the students while the students only listen to and pay attention to the teacher's explanation. This case is in line with the research results of Koulougliotis & Salta (2012) stating that the low motivation in chemistry subject is caused by the application of teacher's learning strategy which is less interesting and involving the students' role.

In learning activity, motivation has a significant role. The students who have high motivation will be actively involved in the learning process and try to learn diligently, feel happy and optimistic in accomplishing the tasks given by the teacher. On the other hand, the students whose learning motivation is low do not attempt hardly to learn. In agreement with the statement of Bereby-Meyer & Kaplan (2005), the factor of motivation plays an essential role in students' learning and strategy transferring of problem-solving. This finding is also supported by the research results of Sevinc et al. (2011) showing that the students with high academic achievement also have high motivation level.

Tuan et al. (2005) addressed that there are six factors which influence learning motivation as stated in SMTSL questionnaire as the indicator of motivation namely: self-efficacy, students' active learning strategies, science learning value, performance goal, the achievement goal, and learning environment stimulation. The followings are the explanations of each indicator of learning motivation: (1) Self-efficacy is students' confidence in their ability to do the learning tasks

well; (2) Students' active learning strategy means that the students take an active role in using any techniques and strategies to build new knowledge based on their previous understanding; (3) Science learning value is letting the students attain the competency of problem-solving and investigate, stimulate their thought and find the relevance of knowledge learned in daily life. If they can feel the principal values of something they learn, they will be motivated to further learn science and knowledge; (4) Performance goal is the student's goal in science learning including competing with the other students to get the teacher's attention; (5) Achievement goal, in this case, the students feel satisfied because they can improve their competency and achievement during the learning; (6) Learning environment stimulation includes the environment in the class, around the students, such as curriculum and interaction between student and teacher and student-student as well as motivation in learning the science and knowledge.

Motivation is a significant pre-requirement and core to learn. Initially, motivation is required to make the students are willing to participate in learning, and then the motivation is needed during the learning process (Rahayu, 2015). The process of the raising of individual's learning motivation is divided into two types namely intrinsic and extrinsic motivations. Intrinsic motivation is the motivation that arises in someone's self, and it is a human's natural tendency to look for and solve the challenge supporting the passion and ability (Woolfoolk, 2010). When someone is intrinsically motivated, he/she does not need incentive or punishment since the activity is interesting and beneficial. Extrinsic motivation is the motivation arising due to the external stimulation. When someone does something to get a reward, avoid the punishment, please the teacher or the other reasons, it can be said that the individual does the academic activity because of extrinsic motivation. Rannikmäe and Holbrook (2009) mentioned that the students' intrinsic motivation could be enhanced by making the science learning interesting and relevant to the students.

One of the learning models involving students' active role is POGIL (Process oriented guided inquiry learning) with SSI context. According to Hanson (2006), POGIL is an inquiry learning oriented to the process and centered on the students in active learning using cooperative learning and guided inquiry to develop the knowledge, the question to improve individual's critical and analytical thinking skills, problem-solving skills, metacognition skills, and responsi-

bility. Learning with POGIL model emphasizes two aspects namely learning topic and learning process (Hanson, 2006; Moog et al., 2009; Straumanis, 2010). The goal of learning using POGIL is to increase the learning process and guide the students to have a conceptual understanding of the topic being learned (Moog & Spencer, 2008). The steps of POGIL include five stages (Hanson, 2005) namely: orientation, exploration, concept formation, application, and closing.

POGIL has three principal components, namely cooperative learning, guided inquiry, and metacognition. Cooperative learning provides a competitive learning environment in which the students will learn and understand better as well as remember more things when they work cooperatively (Hanson, 2005). The guided inquiry learning in POGIL is by involving the students actively and encourage them to restructure their information and knowledge by using a learning cycle consisting of five stages namely orientation, exploration, concept formation, application, and closing/conclusion (Hanson, 2005). POGIL also demands the students to utilize metacognition so that they are aware that they must be responsible for their learning, they need to reflect what they have learned and what they have not understood. Straumanis (2010) explained the benefits of POGIL that is the students can process the information, think critically, solve the problem, communicate, be cooperative in teamwork, manage, and do self-assessment.

Some research results of the effectiveness of the use of POGIL in the chemistry learning are such as the research results of Sen & Yilmaz (2015) exhibiting that the students were more interested in and enjoyable with the chemistry learning using POGIL. Yalcinkaya & Erdur-Baker (2012) asserted that the learning involving the solving of the problem in the real world through group teamwork could improve the students' self-efficacy and learning motivation. Widyaningsih et al. (2012) based on the research result mentioned that through POGIL, most of the students actively and critically thought in the class or laboratory. Maulidiawati (2014) concluded that cooperative learning using POGIL was effective in students' learning outcome for the topic of solubility and the multiple results of solubility as well as it could improve the students' learning motivation.

Based on the research results of POGIL above, it can be concluded that POGIL can improve student's learning motivation. However, to support the implementation of POGIL model and to make it more interesting and the students' learning motivation enhances by using learning

context which is relevant to the daily life. One of the contexts that can be used in POGIL is SSI (socio-scientific issues). Learning with SSI context is a learning approach that studies the facts, phenomena, or occurrences based on the social issues related to science in the society (Ratcliffe & Grace, 2003). POGIL with SSI context performs the problems that are close and relevant to the students' life. The solving of these contextual problems is then searched through active discussion done by the students and their friends in a group. SSI involves the use of topic or scientific problems that obligate the students to be involved in the dialogue, discussion, and debate. The problems presented in SSI are controversial in nature, but they have additional elements that need moral reasoning level or evaluation of ethic problem in the process of decision making about the possibility of issues-solving (Zeidler & Nichols, 2009).

The implementation of POGIL model with SSI context in learning can help the teachers to ensure all students are actively involved in the learning process with the role performed by each student; the learning team in POGIL consists of four people who have a role. This case is in accordance with the statement of Moog et al. (2009) that giving the role to each student could improve the student's involvement by giving special responsibility and helping the students to develop any skills related to each role. The students' main role as the member of a group is active involvement in the group discussion. According to Moog et al. (2009) & Straumanis (2010), besides the main role, the students also get special roles such as being a manager (assuring that all group members perform their role), presenter (presenting the report verbally), recorder (recording the results of group discussion), and reflector (observing and giving comment about the group dynamic). Besides, by discussing SSI cases, the students will be more interested in learning since the things being discussed are related to the daily life-problems that they have known so that their passion and motivation to learn chemistry increase. Rahayu (2016) stated that the cases that are relevant and familiar to the students would visualize the abstract concepts well to make them more concrete and the students can apply their understanding in SSI debate. Besides, SSI is potential to minimize the problem regarding class management and provide the problem-solving as well as the students' opportunity to better understand the topic of chemistry (Rahayu, 2016).

Electrolyte solution and redox reaction are the topics of chemistry taught to the Vocational High School students of class X for the

program of Technology and Engineering expertise. Both topics are the basic topics required to learn electrochemistry. The characteristic of the electrolyte solution and redox reaction topics is many of them which are abstract. For instance, in the electrolyte solution topic, the students could not explicitly observe ions moving freely in the electrolyte solution so that it caused the electrolyte solution could conduct the electrical charge. In redox reaction topic, the students also could not directly observe the occurrence of oxygen release and acceptance, or the process of giving and receiving an electron from certain atom to another atom. Due to this abstract characteristic of the topic, the students are hard to learn the electrolyte solution and redox reaction topics.

Some research results present the difficulties in the electrolyte solution, and redox reaction topics such as Garnett & Treagust (1992) reported that some students were confused about the characteristics of electrical current in the metal conductor and an electrolyte solution. Furthermore, Garnett & Treagust (1992) mentioned that redox reaction is a difficult topic to be understood since it includes abstract topics so that the students were hard even wrong in learning the redox reaction topic. Soudani et al. (2000) found that the students faced difficulty in using theoretical knowledge of redox to interpret the daily phenomena. The students' difficulty in learning electrolyte solution and redox reaction theories caused the students were less interested in chemistry subject, and their learning motivation was low.

Based on the characteristics and problems of chemistry learning in VHS that have been ex-

plained before, to overcome the low motivation of VHS students in chemistry learning especially in electrolyte solution and redox reaction topics is by applying the learning model that involves the students in learning process and using learning context related to the daily phenomena or in accordance with the expertise competency that is by using POGIL with SSI context. Therefore, this work aimed to test whether there is a difference in learning motivation of VHS students taught using POGIL with SSI context, POGIL, and conventional learning and testing the effectiveness of POGIL with SSI context on VHS students' learning motivation.

## METHODS

This research used a quasi-experimental design with pre-test - post-test control group design. The subjects of this research were the students of class X in the State Vocational High School 9 of Malang for the expertise competency of Motorcycle Engineering (ME) academic year of 2016/2017 consisting of three classes with similar initial ability. The experiment 1, experiment 2 and control classes were determined by lottery so that class X of Motorcycle Engineering 2 was chosen as the experiment 1 class that would be taught using POGIL with SSI context, class X of Honda Motorcycle Engineering as the experiment 2 class that would be taught using POGIL and class X of Motorcycle Engineering 1 as the control class that would be taught using conventional learning. This research design is shown in table 1.

**Table 1.** Scheme of Research Design

Group	Pre-test	Treatment	Post-test
Experiment 1	O	X <sub>1</sub>	O
Experiment 2	O	X <sub>2</sub>	O
Control	O	-	O

(Adapted from Creswell, 2012)

Note:

- O : Observation (pre-test and post-test of learning motivation)  
 X<sub>1</sub> : Learning using POGIL with SSI context  
 X<sub>2</sub> : Learning using POGIL

Before conducting the research, the researchers proposed permit to the head of Education Department of Malang City. Moreover, the

Education Department of Malang City recommended the State Vocational High School 9 of Malang in order the researchers were permitted

to research the State Vocational High School 9 of Malang. By the recommendation from the Education Department of Malang City, the researchers asked for permission to the headmaster of the State Vocational High School 9 of Malang. After attaining a permit from the headmaster, the researchers called the chemistry teacher teaching in class X of Motorcycle Engineering and asked for permission to involve the students of class X of Motorcycle Engineering as the research subject. The students in experiment 1 and two classes were given an explanation of POGIL model that would be implemented in the learning of electrolyte solution and redox reaction topics.

Instruments used in this research consisted of two types namely treatment instrument and measurement instrument. Treatment instrument was utilized in the learning process in experiment 1 and two as well as control classes, and it consisted of the syllabus, lesson plan, and Student Worksheet of the electrolyte solution and redox reaction topics. The treatment instruments in the three classes used as the research subjects were different in accordance with the applied learning model. Before using the instrument to collect the data, all treatment instruments were validated by three experts namely two chemistry lecturers of the State University of Malang and one chemistry teacher of Vocational High School. The results of expert validation showed that all treatment instruments were categorized valid and feasible to be employed as a research instrument.

Measurement instrument was in the form of learning motivation questionnaire used to measure the students' motivation in chemistry learning in experiment 1, experiment 2, and control classes. The motivation questionnaire used in this research was adapted from the motivation questionnaire developed by Tuanet al. (2005) which is Student's Motivation Toward Science Learning (SMTSL) Questionnaire consisting 35 items;

each question item has five answer-choices, they are: extremely disagree, disagree, doubt/abstain, agree, extremely agree. Learning motivation measured using SMTLS questionnaire refers to six aspects namely self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation.

Before using the instrument of motivation questionnaire to collect the data, this instrument was validated by two chemistry lecturers from UM and one chemistry teacher from VHS. The results of validity test of the content of motivation questionnaire exhibited a very high value of validity (validity = 91%). The results of the trial test of learning motivation questionnaire indicated that all options in that questionnaire are categorized as valid, and the test reliability had the value of alpha = 0.824. The reliability score of the research instruments is categorized as very high so that it is feasible to be used as research instrument.

The data collection in this research was conducted in 12 meetings. The researchers became the teacher doing learning treatment, giving the test, and collecting the data of the results of treatment and measurement. The data attained from the results of the questionnaire of students' learning motivation was descriptively analyzed to know the percentage of students' learning motivation for each criterion (high, moderate, low). Subsequently, the statistical analysis was done using covariant analysis (ANCOVA) with the score of pre-test as the covariate to test whether there was a difference in learning motivation of students in experiment 1, experiment 2, and control classes.

The following table 2 is the example of stages of POGIL with SSI context as well as the activities of students and teacher in learning the electrolyte solution topic.

**Table 2.** Stage of POGIL with SSI Context

No	Stage of POGIL with SSI Context	Students' Learning Activity	Teacher's Help
1.	Problem orientation with SSI	<ul style="list-style-type: none"> <li>Observing picture or video of people looking for fish using electrical current.</li> <li>Writing and formulating inference based on the picture or video presented by the teacher.</li> <li>Determining a question that will be investigated further.</li> </ul>	<ul style="list-style-type: none"> <li>Displaying video by asking the students to make inference</li> <li>Directing the students to make the questions that will be investigated.</li> </ul>

2.	Problem exploration based on the SSI context	<ul style="list-style-type: none"> <li>Forming group in conformity with the teacher's briefing</li> <li>Sharing role with the group members (manager, presenter, recorder, and reflector)</li> <li>Conducting exploration activity based on the guideline in the Student Worksheet. This exploration activity can be experiment or literary study</li> </ul>	<ul style="list-style-type: none"> <li>Dividing the students into groups</li> <li>Explaining the rule of group discussion fitting with each student's role</li> <li>Guiding the students to explore, experiment, and accomplish the Student Worksheet</li> </ul>
3.	Concept formation	<ul style="list-style-type: none"> <li>Reporting the results of group exploration in front of the class to form the learned topic concept</li> <li>Self-construction of topic concept with the briefing of questions in the Student Worksheet</li> </ul>	<ul style="list-style-type: none"> <li>Asking the students to discuss the results of group exploration</li> <li>Guiding the discussion activity</li> <li>Reinforcing the concept</li> </ul>
4.	Application through discussion of SSI case	<ul style="list-style-type: none"> <li>Analyzing article of SSI through discussion activity with the group members</li> <li>The student representation explains the analysis results of given SSI problems</li> </ul>	<ul style="list-style-type: none"> <li>Presenting article of SSI and asking the students to discuss it in the group</li> <li>Pointing presenter from some groups to present the results of group discussion</li> </ul>
5.	Closing	<ul style="list-style-type: none"> <li>Driving a conclusion of topic that has been learned</li> <li>Reflecting the learning experience and obtained knowledge (self-assessment)</li> </ul>	<ul style="list-style-type: none"> <li>Guiding the students to drive a conclusion</li> <li>Guiding the students to do reflection</li> </ul>

The SSI cases utilized in learning the electrolyte solution topic are such as: (1) *The dilemma of the use of a stunning tool to catch fish*. These SSI cases were related to the topic of solution conductivity in which the students were given a certain article of fishing by using electrical current causing the fishes are easy to find, but in another side, the use of this electrical current can damage the environment ecosystem. In this case, the students were expected to be able to identify why the fishes could die if people fished by stunning and how did the students respond the way of finding fishes by using electrical current; (2) *Battery: advantage and danger*. For this case, various types of battery and its chemical reaction were presented. Based on the chemical reaction presented by students, they were expected to be able to identify the compound of electrolyte substance of the battery. Besides, the students were also involved in the debate of advantage and danger of the battery. Through this debate, the students were actively engaged in learning.

The SSI cases employed in redox reaction topic learning are such as: (1) *Motorcycle and car cause the biggest carbon emission in Indonesia*. In this case, the reactions in fuel combustion process were presented in which most of the gases result-

ed contribute to the air pollution. Through the chemical reactions in the fuel combustion process presented, the students were expected to be able to determine the type of oxidation and reduction reactions based on the oxygen bonding and releasing; (2) *Hydrogen Fuel Cell: Indonesian Future Energy*. Hydrogen fuel cell is a future energy source that has eco-energy with the combustion process that only results in water and energy (electricity and heat). However, the use of this fuel cell also raises the debate because it turns out that the result of the reaction of hydrogen and oxygen is not only water, but UV ray becomes its side product, and explosion risk are very vulnerable to the usage. In this case, the example of chemical reaction occurring in a fuel cell was also presented so that the students were expected to be able to understand the oxidation and reduction reactions based on the electron releasing and receiving; (3) *Cigarette and Its Danger*. In these SSI cases, the substances containing cigarette were presented so that the students were expected to be able to identify and determine the number of oxidation of elements containing a cigarette; (4) *Corrosion is occurring to the motorcycle bars due to the scratch of zinc layer*. The corrosion happening to the motorcycle bars because of the scratch of zinc layer is a case which is very relevant to the students of

VHS, Motorcycle Engineering Department. By presenting this case, the learning was expected more interesting, and the students could understand the oxidation-reduction reactions based on the change of the number of oxidation; (5) *Chemical substance in clothing whitener*. Clothing whitener is an example of redox reaction application in daily life. The clothing whitener is the process of chemical reaction in which the dirty molecules will be broken into smaller parts so that it is easier to be lifted by surfactant (stain lifter). Whitener solution sold in the market usually contains active material of sodium hypochlorite in which the production process of NaOCl involves the autoredox reaction. By presenting this case, the students were expected to be able to understand the autoredox reaction.

By presenting such above examples of daily cases which are relevant to the electrolyte solution and redox reaction, the students were expected to be more interested in chemistry learning, and VHS students' learning motivation could increase. The followings are the examples of SSI presented in redox reaction topic learning.

## RESULTS AND DISCUSSION

The results of a students' learning motivation questionnaire given before and after they learned electrolyte solution and redox reaction were then tabulated and descriptively analyzed to obtain the data of the percentage of students' motivation based on the criteria presented in table 3.

**Table 3.** Percentage of Students' Learning Motivation Based on the Criteria

CLASS	Criteria of Motivation	Pre-test (%)	Post-test (%)
Experiment 1	High	-	79
	Moderate	76	21
	Low	24	-
Experiment 2	High	-	60
	Moderate	80	36
	Low	20	4
Control	High	-	7
	Moderate	75	75
	Low	25	18

Based on the data presented in table 3, there was an improvement of students' learning motivation indicated by the increase in students who had high and moderate motivation and the

decrease in the students who had low motivation at the end of learning. The data of pre-test and post-test scores of students' learning motivation questionnaire are presented in table 4.

**Table 4.** Mean of Pre-Test and Post-Test of Students' Learning Motivation

CLAS	Mean of Pre-Test	Mean of Post-Test	Gain Score
Experiment 1	89.59	135.48	45.90
Experiment 2	89.68	128.48	38.80
Control	89.61	102.61	13.00

Table 4 shows that there was an increase in scores of the students' learning motivation in experiment 1, experiment 2, and control classes. This case means the students' learning motivation changed after the learning process of the electrolyte solution and redox reaction. Before doing a hypothesis test to the scores of the students' learning motivation, the analysis pre-requirement test was conducted in the form of normality and

homogeneity tests. Normality test of the scores of students' learning motivation in experiment 1, experiment 2, and control classes was carried out using One-Sample Kolmogorov-Smirnov Test in the trust level of 95% ( $\alpha = 0.05$ ) assisted by IBM SPSS Statistics 20 for Windows program. The results of normality test for the three classes are presented in table 5.

**Table 5.** Results of Normality Test of Students' Learning Motivation

CLASS		Experiment 1	Experiment 2	Control
N		29	25	28
Pre-test	Mean	89.59	89.68	89.61
	Std. Dev	6.080	5.475	6.652
	Sig (2-tailed)	0.200	0.200	0.200
Post-test	Mean	135.48	128.48	102.61
	Std. Dev	8.704	15.822	13.209
	Sig (2-tailed)	0.200	0.200	0.200

Based on table 5, the significant values of pre-test and post-test of the students' learning motivation in experiment 1, experiment 2, and control classes were more than 0.05 and thereby it can be concluded that the scores of pre-test and post-test of students' learning motivation in the three classes were normally distributed. The homogeneity test of the scores of pre-test and post-test of the students' learning motivation was done through Levene's test at the trust level of 95% ( $\alpha = 0,05$ ). The homogeneity test of the pre-test scores of the students' learning motivation in the three classes resulted in a significant value of 0.082. The significant values of pre-test and post-test were higher than 0.05, and thus it can be concluded that the scores of pre-test and post-test on the students' learning motivation in experiment 1, experiment 2, control classes had the similar or homogenous variant.

Hypothesis test on the students' motivation was conducted using ANCOVA at the trust level of 95% ( $\alpha = 0.05$ ) assisted by IBM SPSS Statistics 20 for Windows program. The ANCOVA test of the scores of students' learning motivation in the three classes resulted in significant value for the learning model of 0.00 (Sig < 0.05). This case means that there was a significant difference in learning motivation of students taught using POGIL with SSI context in experiment 1 class, POGIL model in experiment 2 class, and conventional model in control class.

To test the calculation results of the three research classes, the further test of Post Hoc was conducted using LSD test to obtain the data of classes which had a real difference. The results of Post Hoc test for the effect of learning model on the students' learning motivation are presented in table 6 as follows.

**Table 6.** Results of LSD Post Hoc Test of the Effect of Learning Model on the Students' Learning Motivation

Dependent Variable	(I) Model	(J) Model	Mean Difference (I-J)	Sig.
Students' learning motivation	POGIL+SSI	POGIL	7.00*	0.048
		Conventional	32.88*	0.000
	POGIL	Conventional	25.87*	0.000

Based on table 6, there was a significant difference in the learning motivation between the students taught using POGIL with SSI context and those taught using POGIL and conventional model (Sig. < 0.05) and there was a significant difference in learning motivation between the students taught using POGIL model and those taught using conventional model (Sig. < 0.05). Table 6 also shows that the students in the class using POGIL with SSI context had the highest

learning motivation compared to those in POGIL and conventional classes.

To know the meaningfulness behind the difference in students' learning motivation, the test of effect size was conducted on the average scores of each aspect of the students' learning motivation measured. The scores of effect size for each aspect of the students' learning motivation are presented in Table 7 as follows.

**Table 7.** Effect Size Scores of Each Aspect of Learning Motivation

No	Motivation Aspect	A		B		C	
		Effect Size	Criteria	Effect Size	Criteria	Effect Size	Criteria
1	Personal effectiveness	1.72	Big	1.30	Big	0.29	Small
2	Active learning strategy	12.63	Big	1.76	Big	0.29	Small
3	Science learning value	1.88	Big	1.19	Big	0.55	Moderate
4	Performance goal	1.32	Moderate	1.29	Big	0.20	Small
5	Achievement goal	1.79	Big	1.18	Big	0.22	Small
6	Learning Environment Stimulation	1.96	Big	1.52	Big	0.57	Moderate

Notes:

A = Effect Size of Experiment 1 and control classes

B = Effect Size of Experiment 2 and control classes

C = Effect Size of Experiment 1 and Experiment 2 classes

The research results using ANCOVA test of the scores of pre-test and post-test of student's learning motivation showed that there was a significant difference in learning motivation of the students taught using POGIL with SSI context, POGIL, and conventional learning. Table 4 provides the information that the average scores of the students' learning motivation in the three classes increased after the learning process. The mean of post-test of the students' learning motivation in POGIL with SSI context was the highest one compared to the mean of post-test of POGIL and conventional classes. These results were supported by the results of Post Hoc test using LSD test exhibiting that the learning motivation in the class of POGIL with SSI context was the highest than that in POGIL class (the different value of mean = 7.00) and conventional class (the different value of mean = 32.88). The students' learning motivation in POGIL class was higher than that in conventional class (the different value of mean = 25.87).

Based on table 3, when pre-test was conducted, no one of all students in the three classes who had high motivation. After the treatment, the students had high motivation in the class of POGIL with SSI context, POGIL, and conventional with the value of 79%, 60%, and 7%, respectively. Meanwhile, the students who had moderate motivation in the class of POGIL with SSI context, POGIL, and conventional obtained the value of 21%, 36%, and 75%. The students with the low motivation in POGIL and conventional classes reached the value of 4% and 18%, respectively,

while in the class of POGIL with SSI context, there was no student who had low motivation after learning process.

Based on the data presented before, it can be concluded that POGIL with SSI context was more effective to improve the students' learning motivation compared to POGIL and conventional learning. This case was caused by some factors. First, POGIL is learning which is oriented on the learning process. The steps in POGIL directed the students to be more active in finding the concept inductively and independently. The students' activeness could be seen in learning activity showing the high learning motivation.

Second, there was a cooperative learning component in POGIL. In the cooperative group of this POGIL class, there was a role sharing for each member to make the learning more interesting and raising the positive interaction between the group members. Learning with a cooperative group can improve confidence, ability to make an asocial relationship by enhancing confidence and teamwork ability of the group members. Hanson (2005) addressed that cooperative learning in POGIL provides a competitive learning environment in which the students could learn better, understand more things, and remember many more things when they work cooperatively.

Third, POGIL with SSI context involves controversial scientific-social issues that should be solved in the group discussion. The presented scientific-social issues are contextual and relevant to the students' life; the relevance of chemistry learning to the real world could enhance



the students' learning motivation. The results of observation done by researcher indicated that in the discussion of SSI, the students were more interested in learning since each group competed to give their opinion on the controversial issues presented. These controversial issues made the discussion process more powerful. Furthermore, the topics discussed were daily problems that had been familiar to students. It was different from what happened in a group discussion in POGIL and conventional classes because the discussion topic was about the application and accomplishment of questions related to the obtained concept. Rannikmäe & Holbrook (2009) asserted that the students' intrinsic motivation could be upgraded by making the science learning interesting and relevant to them.

The results of effect size analysis on the aspects of students' learning motivation as presented in Table 6 showed that POGIL with SSI context and POGIL greatly influenced all aspects of learning motivation measured, namely personal effectiveness, active learning strategy, science learning value, performance goal, achievement goal, and learning environment stimulation. This case is because in POGIL with SSI context and POGIL classes, the students were actively involved in the learning, the SSI cases presentation enabled the students knew the relevance and value of the topic being learned to the daily life through discussion in competitive and cooperative group to increase the students' goal of getting the achievement and performance. Besides, the reflection in the closing stage could train the students' metacognitive skill to evaluate their learning outcome. Bransford et al. (2000) stated that in POGIL, the students were demanded to use metacognition in order the students realize that they should be responsible for their learning and they have to monitor their learning achievement (self-management and self-regulation); the students should reflect the topic they have not understood (reflection in learning), and they have to think of their performance and how to improve it (self-assessment).

The use of SSI as the learning context in POGIL gave moderate effect on the personal effectiveness, science learning value, and learning environment stimulation. This case is because in POGIL with SSI context, the teacher presented a case which was relevant to the topic that would be learned to enable the students to know that there was a relationship of the topic they would learn with the phenomena in life so that the students knew the meaning of learning in life. In the application step, the teacher presented an article

of SSI which was pertinent to the topic of group discussion. The presentation of SSI case could improve the students' motivation to learn. In the aspect of active learning strategy, performance goal, and achievement goal, SSI context brought about small influence. This case is because in POGIL with SSI context and POGIL class, the students were guided to be actively involved in the learning so that they could construct their knowledge by themselves through competitive group discussion. The finding of this research is in line with the previous research conducted by such as Bilgin (2009), Geiger (2010); Sen & Yilmaz (2015) reporting that the students were more interested in and happier in chemistry learning using POGIL. Yalcinkaya & Erdur-Baker (2012) stated that the learning that could involve solving skill of problems in the real world could enhance the students' self-efficacy and learning motivation.

## CONCLUSION

Based on the explanation in this research, it can be concluded that there was a significant difference in learning motivation of VHS students taught using POGIL with SSI context, POGIL, and conventional learning. POGIL with SSI context was the most effective model to improve the VHS students' learning motivation proven by the students' highest learning motivation compared to that in POGIL and conventional learning classes.

## REFERENCES

- Aikenhead, G.S. (2003). Chemistry and Physics Instruction: Integration, Ideologies, and Choices. *Chemical Education: Research and Practice*, 4(2), 115-130
- Bereby-Meyer, Y., Kaplan, A. (2005). Motivational Influences on Transfer of Problem-Solving Strategies. *Contemporary Educational Psychology*, 30(1), 1-22
- Bilgin, M. (2009). The Effect of Guided Inquiry Instruction Incorporating a Cooperative Learning Approach on University Student' Achievement of Acid and Base Concept and Attitude Toward Guided Inquiry Instruction. *Academic Journal Scientific Research and Essay*, 4(10), 1038-1046.
- Bransford, J.D., Brown, A.L., Cocking, R.R., Donovan, M.S., Bransford & Pellegrino, J.W. (Eds). (2000). *How People Learn: Brain, Mind, Experience and School: Expanded Edition*. Washington, D.C: National Academy Press.
- Chang, R. & Overby, J. (2011). *General Chemistry The Essential Concepts Sixth Edition*. New York: Mc. Graw-Hill.

- Creswell, J.E. (2012). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research, Fourth Edition*. Boston: Pearson Education, Inc.
- Garnett, P.J., Treagust, D.F. (1992). Conceptual Difficulties Experienced by Senior High School Students of Electrochemistry: Electrochemical (Galvanic) and Electrolytic Cells. *Journal of Research in Science Teaching*, 29(10), 1079-1099
- Geiger, M. (2010). Implementing POGIL in Allied Health Chemistry Courses: Insight from Process Education. *International Journal of Process Education*, 2(2), 19-34
- Hanson, D.M. (2005). *Designing Process-Oriented Guided-Inquiry Activities*. Listle, IL: Pacific Crest
- Hanson, D.M. (2006). *Instructor's Guide to Process Oriented Guided Inquiry Learning*. Listle, IL: Pacific Crest.
- Holbrook, J. (2005). *Making Chemistry Teaching Relevant*, 6(1), 1-12.
- Koulougliotis, D. & Salta, K. (2012). *Student's Motivation to Learn Chemistry: The Greek Case. New Perspectives in Education*. Greece: Technological Educational Institute (TEI) of Ionian Island.
- Maulidiawati, S. (2014). The Effectivity of Cooperative with POGIL Instruction on Learning Achievement. *Journal Unnes: Chemistry in Education*, 3(2), 163-169
- Moog, R.S., & Spencer, J.N. (2008). *POGIL: An Overview*. Washington DC: Oxford University Press.
- Moog, R.S., Cregan, F.J., Hanson, D.M., Spencer, J.N., Straumanis, A.R. (2009). *Process-Oriented Guided Inquiry Learning: POGIL and the POGIL Project*. (Online), (<http://www.pogil.org>), accessed on 16 July 2015.
- Oloruntegbe, K.O. & Alake, E.M. (2010). Chemistry for Today and The Future: Sustainability Through Virile Problem Based Chemistry Curriculum. *Australian Journal of Basic and Applied Science*, 4(5), 800-807.
- Price, W.S & Hill, J.O. (2004). Raising Status of Chemistry Education. *Chemistry Education*, (8), 13-20.
- Rahayu, S. (2015). Evaluating the affective dimension in chemistry education, in Affective Dimensions in Chemistry Education. In Murat Kahveci & Marykay Orgill (Eds). *Affective Dimensions in Chemistry Education*. Nederland: Springer, pp. 29-49.
- Rahayu, S. (2016). *Improving Indonesian Children Scientific Literacy through Nature of Science (NOS) Oriented Instruction. Book of Inaugural Speech of Mathematics & Science Presented, Presented at open session Senate of Universitas Negeri Malang*. Malang, 17 March 2016.
- Rahayu, S. (2016). Improving Student's Higher Order Thinking Skill through Chemistry Instruction with Socioscientific Issues (SSI) and Nature of Science (NOS). *Proceeding of National Seminar in Chemistry and Its Instruction*. Malang: Chemistry Departement Universitas Negeri Malang, pp. 11-19
- Rannikmae, M & Holbrook, J. (2009). The Meaning of Scientific Literacy. *International Journal of Environmental & Science Education*, 4(3), 275-288.
- Ratcliffe, M. & Grace, M. (2003). *Science Education for Citizenship: Teaching Socio-Scientific Issues*. Philadelphia: Open University Press.
- Refriwati. (2015). Improvement Students' Learning Motivation using Problem-Based Learning Approach on Chemistry Topic of TSM Grade 11 SMKN 1 Bukit Sundi Kabupaten Solok. *Jurnal Educatio, Jurnal Pendidikan Indonesia*, 1(1), 36-42.
- Sen, S. & Yilmas, A. (2015). The Effects of Process Oriented Guided Inquiry Learning Environment on Students' Self-regulated Learning Skills. *Problem in Education of 21th Century*, 66, 54-66.
- Sevinc, B., Ozmen, H., & Yigit, N. (2011). Investigation of Primary Students' Motivation Levels towards Science Learning. *Science Education International*, 22(3), 218-232
- Sitepu, C.P.K. (2016). The Effect of Chemskeith Media in Instruction used Recitation Method on Chemistry Achievement and Motivation at Vocational School Grade XI. *Scientific Journal "Integritas"*, 2(1), 1-19.
- Soudani, M., Sivade, A., Cros, D., Medimagh, M.S. (2000). Transferring Knowledge from the Classroom to the Real World: Redox Reaction. *Journal of Technology Education*, 24(1), 2-17
- Straumanis, A. (2010). *Classroom Implementation of Process Oriented Guided Inquiry Learning. A practical guide for instructors*. Stony Brook University: Pacific Crest.
- Tuan, H., Chin, C., Shieh, S.H. (2005). The Development of a Questionnaire to Measure Students' Motivation Towards Science Learning. *International Journal of Science Education*, 27(6), 639-654
- Widyaningsih, S.Y., Haryono, Saputro, S. (2012). Model of MFI and POGIL Viewed from Learning Activities and Student Creativity to Learning Achievement. *Inquiri Journal*, 1(3), 266-275.
- Woolfolk, A. (2010). *Educational Psychology 11th Ed.* USA: Pearson Education, Inc
- Yalcinkaya, E., Boz, Y., Baker, O.E. (2012). Is case-based instruction effective in enhancing high school students' motivation toward chemistry? *Science Education International*, 23(2), 102-116
- Zeidler, D.L., Nichols, B.H. (2009). Socioscientific Issues: Theory and Practice. *Journal of Elementary Science Education*, 21(2), 49-58.



## ANALYSIS OF SCIENCE PROCESS SKILLS OF SUMMATIVE TEST ITEMS IN PHYSICS OF GRADE X IN SURAKARTA

D. Ratnasari\*<sup>1</sup>, Sukarmin<sup>2</sup>, Suparmi<sup>3</sup>, D. Harjunowibowo<sup>4</sup>

<sup>1,2,3</sup>Master's Degree Program in Science Education, the Faculty of Teacher Training and Education,  
Sebelas Maret University Surakarta

<sup>4</sup>Department of Architecture & Built Environment, the Faculty of Engineering, University of Nottingham

DOI: 10.15294/jpii.v7i1.10439

Accepted: November 17<sup>th</sup>, 2017. Approved: February 19<sup>th</sup>, 2018. Published: March 19<sup>th</sup>, 2018

### ABSTRACT

The objective of this research is to analyze the science process skills (SPS) of the summative test items in physics in Surakarta. This research used a descriptive method with content analysis, namely: summative test items in Academic Year 2015/2016 in Surakarta. Each item was analyzed based on science process skill indicators prepared and elaborated by the researchers. The result and discussion of the research showed that the SPS found in the summative test items in Physics in Surakarta included those of formulating hypotheses (2.88%), designing experiments (2.10%), interpreting data (5.10%), applying concepts (70.20%), communicating (6.64%), and drawing conclusions (13.08%) respectively.

© 2018 Science Education Study Program FMIPA UNNES Semarang

**Keywords:** Science process skills; summative test items

### INTRODUCTION

The aims of the education and science education today are to educate individuals who are able to adapt themselves in the different conditions, to think flexibly, to ask actively, to be creative, to think critically, to solve problems, and to appreciate other's opinions. One of which, namely: to solve problems, can be achieved with the SPS (Aktamis & Yenice, 2010). According to (Carey, et al., 1989), Science Process Skills (SPS) are special skills to simplify the science learning, to encourage students to be active, to develop students' sensitivity toward learning, and to make concepts that they have learned remain still in their mind by teaching them using scientific methods.

Comprehension learning will guide the students to connect their new experiences to their

previous experiences and concepts. Science learning with comprehension learning makes them able to describe concepts, make predictions, raise questions, examine predictions and interpret data. In other words, comprehension learning means learning by using the SPS (Harlen, 1999). In many countries, learning with the SPS has become an important component of the science curriculum at all levels and has also become one of the newest approaches in education science.

The 2013 curriculum explains that assessment on students' performance in the learning process is closely associated with their thinking skills. The students' thinking skills in building a new concept of science learning can be trained through the development of the SPS. The American Association for the Advancement of Science (AAAS) claimed that the SPS are very suitable for science learning, and science learning must be directed to learning that makes the students active, gives them real experiences, and trains their

\*Correspondence Address:

E-mail: dewi\_ratnasari@student.uns.ac.id

thinking ability.

In recent decades, Science teachers have their attention focused on the basic SPS and the integrated SPS. The SPS are very crucial for meaningful learning as the learning itself goes in the daily life, and students should be able to find, interpret and look for evidences through different conditions encountered (Karamustafaoglu, 2011).

Öztürk & Tezel, 2010 stated that SPS are a set of procedures done by scientists to conduct an investigation in an attempt to develop the knowledge. Extended training on SPS to students and developing students' SPS will be very useful for them not only as the process of building their knowledge and learning but also as their resources in everyday life.

To reach the objectives, the development of the curriculum which counts heavily on the SPS needs a feasible instrument which is able to evaluate the enhancement of SPS. Harlen (1999) stated that SPS without assessment would make the learning meaningless. Therefore, the development of an assessment instrument should be adapted to the science process skill indicators.

The importance of SPS assessment has widely been expressed by previous researchers. One of them is Harlen (1999). He stated that SPS cannot be separated from the understanding of concepts used in learning and in science implementation. However, the importance of these skills must be applied to other materials (besides science) because the core of learning is comprehension, both in formal education and everyday life. That is the reason why assessment in the SPS is important.

The results of research conducted by Hofstein & Lunetta, (2004) suggested that some schools still fail to assess the results of laboratory activities appropriately. Further, Hofstein & Lunetta emphasized the importance of authentic assessment alternative, which is able to measure SPS in school. However, although digital era primarily focused on a high standard approach to science education, the assessment model in a science lab is still conventional through the use of paper and pencil test. In addition, measurements for developing standardized test forms have not maximally been done. As a result, the development and the assessment of the SPS become important. Although there are difficulties in the implementation of the authentic skill assessment, the technical problems can be solved as long as there is a will to do so (Temiz, 2006).

One of the assessments conducted by the teachers is the scoring on the summative test. The materials of the summative test items contain matters that the teachers have taught in one semester. The summative test became one of the students' comprehension benchmark of the materials. However, the development of summative test generally is focused on the cognitive aspect, without considering the student's SPS. This causes the concept to be less internalized to the students' mind as they are required to merely memorize, not to do a process of digging the information. Thus, the objectives of this research are to analyze the summative test items in Surakarta and to investigate to some extent how the SPS are applied in the assessment.

## METHODS

This research used the descriptive method. A design of descriptive research attempted to illustrate; what, how, or why something happens. A descriptive research uses samples to document, describe, and explain whether or not there are phenomena in the studied matter. The data of the research were collected through content analysis, namely: the analysis of the summative test items in Academic Year 2015/2016, which was used in some schools in Surakarta. Purposive sampling technique was employed to determine its samples by selecting the schools that represented the high, medium, and low categories of both state and private schools. The samples consisted of 6 samples of summative test items from six different schools in Surakarta.

The data of the research were collected through a checklist, which was prepared according to the science process skill indicators. The science process skill indicators in this research included formulating hypotheses, designing experiments, analyzing the data, applying concepts, communicating, and drawing conclusions. Each item was analyzed based on the science process skill indicators. The occurrence of each indicator was tabulated, and the average of the occurrence of each indicator was then calculated. In addition, the analysis was also done on the material's categories. The results were tabulated and averaged. Based on the average of science process skill indicators' occurrence, it could be known how the summative test items in Surakarta were developed. The SPS indicators which were too dominant and the indicators which did not appear at all could be analyzed.

## RESULTS AND DISCUSSION

The summative test items from some schools in Surakarta were analyzed based on the six SPS indicators with their aspects. The analysis was conducted on each item and material in the summative test items in Physics of Grade X in

Semester 2 in Academic Year 2015/2016, which consists of the learning materials of Elasticity; Static Fluid; Heat, Temperature and Heat Transfer; and Optical Instrument. Each occurrence indicator was calculated and averaged. The result of material analysis based on the SPS is presented table 1.

**Table 1.** The Analysis Result of the SPS on Each Learning Material (Continued)

Material	Summative Test A						Summative Test B						Summative Test C					
	SPS Indicators						SPS Indicators						SPS Indicators					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Elasticity	0	0	0	5	1	0	0	0	1	5	3	2	0	0	1	4	0	0
Static Fluid	0	1	0	5	0	2	2	1	0	8	0	4	1	1	3	4	0	0
Heat, Temperature and Heat Transfer	0	0	0	13	0	0	0	0	0	8	0	3	0	0	1	9	0	2
Optical Instrument	0	0	1	11	0	1	0	0	0	4	3	2	0	0	0	9	0	0
Occurrence Average	0	1	1	33	2	3	2	1	1	24	6	11	1	1	5	26	0	2
Total Item	40						45						35					
Percentage (%)	0	2.5	2.5	82.5	5	7.5	4.4	2.2	2.2	53.3	13.3	24.4	2.9	2.9	14.1	74.1	0	5.7

Material	Summative Test D						Summative Test E						Summative Test F					
	SPS Indicators						SPS Indicators						SPS Indicators					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Elasticity	0	0	1	5	3	1	0	0	1	3	2	1	0	0	1	2	0	1
Static Fluid	0	2	0	9	0	0	0	0	0	7	0	3	1	0	0	4	0	2
Heat, Temperature and Heat Transfer	0	0	0	10	0	0	0	0	1	6	0	3	2	0	0	11	0	0
Optical Instrument	0	0	0	6	2	2	0	0	0	8	0	0	0	0	0	4	1	1
Occurrence Average	0	2	1	29	5	3	0	0	2	24	2	7	3	0	1	21	1	4
Total Item	40						35						30					
Percentage (%)	0	5	2.5	72.5	12.5	7.5	0	0	5.7	68.6	5.7	20	10	0	3.33	70	3.3	13.3

Notes:

Indicator 1: formulating hypotheses; Indicator 2: designing experiments; Indicator 3: analyzing data; Indicator 4: applying concepts; Indicator 5: communicating; indicator 6: drawing conclusions

Table 1 shows kinds of SPS that appeared on the summative test items. On Summative Test A, the skill of formulating hypotheses did not appear at all. Meanwhile, the skill of applying concepts became the most dominant skill which was 82.5%. The skills of designing experiments and analyzing the data only appeared in 1 question

item of each learning material. The skill of applying concepts became the most dominant skill on each material. On the materials of Heat, Temperature and Heat Transfer, the skill of applying concepts (Skill 4) appeared in each test item while the skills of 1, 2, 3, 5 and 6 did not appear at all.

On Summative Test B, the SPS indicators was more evenly spread compared to the Summative Test A though the skill of applying concepts still became the one that appeared mostly on the question items. All of the SPS indicators which were analyzed appeared on Summative Test B. Thus there was no percentage occurrence of 0. However, similar to Summative Test A, on the materials of Heat, Temperature, and Heat Transfer, almost all question items were in the form of skill of applying concepts, while the skills of formulating hypotheses, designing experiments, analyzing data and communicating did not appear at all.

Summative Test C was not much different from Summative Test A and B. The skill of applying concepts still became the skill that often appeared on each summative test. While the skill of communicating did not appear at all on each material. In Optical Instrument material, the skill that appeared was that of applying concepts. The certain skills that appeared made the question items less variation and only able to measure one type of skill.

Summative Test D had a pattern of occurrence which was almost similar to the others. The dominant skill was the skill of applying concepts. The skills of formulating hypotheses became the skill whose percentage occurrence was 0%. On the materials of Temperature, Heat, and Heat Transfer, the skill that appeared was that of applying concepts while other skills did not appear at all.

The skill of applying concepts also became the indicators which often appeared on Summative Test E. Even on the material of Optical Instrument, the skill of applying concepts was the only skill that appeared. The skill of formulating hypotheses and that of designing experiments did not appear at all on each material.

Summative Test F was also similar to Summative Tests A, B, C, D, and E. They were still dominated with the skill of applying concepts while the other skills only appeared on some materials or did not appear at all.

Based on the analysis of each Summative Test, the occurrence pattern of indicators was almost similar on each summative test. The frequently occurred indicator was the skill of applying concepts while the indicators that rarely occurred were formulating hypotheses and designing experiments.

Duruka, et al., 2017 stated that the hypotheses were data based on the previous knowledge and repeated observations; or, explanations concluded from observations. This skill became one of the skills that rarely appeared on each summative test. This should be a concern because this skill becomes one of the important components in science learning. It is similar to the claim of Kuhn & Dean, (2005) who stated that the skill of formulating hypotheses becomes an important component in scientific and inquiry matters, since it is important for the students to search for information by submitting hypotheses so that the students will attempt to find out the answers to the hypotheses.

Besides, the skill of designing experiments also becomes an important component in science. It is similar with Karamustafaoğlu (2011) who stated that SPS are developed based on the activity of the laboratory. Through the activities of the laboratory, the students gain meaningful learning, use the SPS, and become familiar with the process of constructing the information obtained in the science learning.

After the summative test was analyzed, each indicator was summed up and averaged by their occurrences. The data analysis result of each science process skill indicator are presented in table 2.

**Table 2.** Analysis of Each Science Process Skill Indicator

Science Process Skill Indicators	Summative Test												Average
	Summative Test A		Summative Test B		Summative Test C		Summative Test D		Summative Test E		Summative Test F		
	Σ	(%)	Σ	(%)	Σ	(%)	Σ	(%)	Σ	(%)	Σ	(%)	
Formulating Hypotheses	0	0	2	4.4	1	2.9	0	0	0	0	3	10	2.9
Designing experiments	1	2.5	1	2.2	1	2.9	2	5	0	0	0	0	2.1
Analyzing Data	1	2.5	1	2.2	5	14.3	1	2.5	2	5.7	1	3.3	5.1

Applying Concepts	33	82.5	24	53.3	26	74.3	29	72.5	24	68.6	21	70	70.20
Communicating	2	5	6	13.3	0	0	5	12.5	2	5.7	1	3.3	6.6
Drawing Conclusions	3	7.5	11	24.4	2	5.7	3	7.5	7	20	4	13.3	13.1
Total Items	40		45		35		40		35		30		

Table 2 shows the average occurrence of each indicator at all summative tests which made the samples can be analyzed. The indicators having the largest percentage of occurrence on average was the skill of applying concepts, which was 70.20%.

The domination of the skill of applying concepts indicated that Physics learning was all this time oriented to memorizing concepts not to find concepts. This should become our serious concern because the students should gain a meaningful learning through SPS. According to Harlen (1999), through meaningful learning, the students will continue to learn throughout their life. It is, therefore, very important to give SPS in educational institutions.

The skill of designing experiments became a skill that had the least percentage occurrence. The skill should be the compulsory one extended to the students. Akani (2015) stated that designing experiments and observation became a key to activity in science learning, so that it became an important component in learning, teaching and implementing science. Germann (1994) revealed that the primary purpose of science learning was to help the students to construct knowledge-centered phenomenon in science, and at the same time, to help the students to disclose the reasons, think critically, and to resolve the issues. One of the ways to materialize it is inquiry-based learning in the laboratory, which emphasized the basic SPS and the integrated SPS.

The importance of designing skill experiments was also expressed by Duruka et al. (2017) who stated that discovery-based learning would make the students use the high level thinking skill to draw conclusions based on the evidence. In the process of designing experiments, the students used some skills of science such as; collecting data, identifying variables, formulating hypotheses, and others. Meanwhile, the skills of designing experiments became the important SPS due to the combination of many skills for deeper analysis when conducting the experiment repeatedly.

In addition to the skill of designing experiments, the skill of formulating hypotheses beca-

me one of the skills which appeared little on the summative test. The average occurrence of this skill was 2.88%. The skill of formulating hypotheses was inseparable from the skill of designing experiments. Both became the characteristics of the science learning. One of the caused of the low average occurrence of formulating skill hypotheses was that the textbook used by the teachers did not contain SPS. This result of the research is in line with that of the research conducted by Tatar & Feyzioglu (2012) who claimed that most of the results of the study show that the science textbook for Senior Secondary Schools did not contain SPS or contain SPS which are separable at each level and which have the smallest representation on the skill of formulating hypotheses.

Other skills such as the skill of analyzing data, the skill of communicating, and the skill of drawing conclusions also had a low level of occurrence. According to Sukarno et al. (2013), the low percentage of the occurrence of SPS indicators is due to the fact that the assessment of students' competence all this time only has only been focused on the mastery of concepts. Besides, the teachers less understand how to develop an instrument which is capable of measuring the SPS of the students. Furthermore, Sukarno et al. (2013) stated that one way to overcome this situation is providing the science teachers with the training of SPS. The training consists of knowledge of the SPS, the SPS indicators, and the SPS assessment. Through training, teachers are expected to be able to apply their knowledge in developing the SPS through their students.

The results of research conducted by Foulds & Rowe, (1996) showed that teachers and students still rarely develop the SPS. The students have weakness in developing the skill analyzing problems, and in designing and controlling the experiments. The science learning integrated with the development of science process skill demands a laboratory activity. Thus, teachers are expected to be able to improve the students' SPS through the laboratory activity.

SPS are thinking skills used by scientists to build knowledge for problem-solving. Scientific

methods, scientific mindsets, and critical thinking are terms of this skill, so that for at least two decades, SPS have become more commonly heard (Özgelen, 2012)

The importance of the SPS has been widely recognized. The SPS become the main goal of the science learning. It is used not only by scientists, but also by everyone who wants to be an educated scientist. It can be said that teaching the science means teaching the SPS (Harlen, 1999; Mohd, 2004)

The SPS have become the important skills, not only for the preparation of scientists and technologists in the future, but also for the vast majority of people who need science literacy for life where science affects most aspects of personal, social and global life (Harlen, 1999). The SPS will help students to become problem-solvers so that they are able to apply these skills in the context of the real world (Monhardt & Monhardt, 2006).

The SPS also have a positive impact on the learning achievements of students. Earlier studies showed a positive correlation between the academic achievement and the SPS (Beaumont-Walters & Soyibo, 2001; Delen & Keserciodlu, 2012; Sinan & Usak, 2001). The SPS and the academic achievement are interconnected for the students 'conceptual change process. To develop a high level of conceptual changes requires the SPS. Therefore, the SPS cannot be separated from the conceptual changes and conceptual understanding (Karamustafaoglu, 2011).

The SPS can be seen as factors that support the understanding of the concepts because the SPS are correlated with the academic achievement. The students' ability in mastering the concepts of Physics requires some skills, such as skills to solve problems, SPS and ability of thinking and reasoning (Usmeldi, 2016). In addition, according to Rani, et al. (2017), the SPS are also needed to get an understanding of the concepts in the learning process.

The importance of SPS in science learning including Physics and the positive correlation between the SPS and the academic achievement become the reason of why the assessment including the SPS indicators become very important to be developed. Assessment can be done through the daily test, semester-mid test, or summative test.

## CONCLUSION

In conclusion, the average occurrences of the science process skill indicators on the summative test items in Surakarta were as follows: (1) the skill of formulating hypotheses was 2.88%;

(2) the skill of planning experiments was 2.10%; (3) the skill of analyzing data was 5.10%; (4) the skill of applying concepts was 70.20%; (5) the skills of communicating was 6.64%; and (6) the skill of drawing conclusions was 13.08%.

The results of this research are expected to be a reference for teachers who want to develop assessment instruments that contain the SPS indicators. The disadvantages and advantages of each summative test item can be a reference for the development of summative test items in the next academic year.

## REFERENCES

- American Association for the Advancement of Science (AAAS). (1967). *Science-A Process Approach*. Washington, D.C: American Association for the Advancement of Science.
- Akani, O. (2015). Levels of Possession of Science Process Skills by Final Year Students of Colleges of Education in South-Eastern States of Nigeria. *Journal of Education and Practice*, 6(27), 94-101.
- Aktamis, H., & Yenice, N. (2010). Determination of The Science Process Skills and Critical Thinking Skill Levels. *Procedia-Social and Behavioral Sciences*, 2(2), 3282-3288.
- Beaumont-Walters, Y., & Soyibo, K. (2001). An Analysis of High School Students' Performance on Five Integrated Science Process Skills. *Research in Science & Technological Education*, 19(2), 133-145.
- Carey, S., Evans, R., Honda, M., Jay, E., & Unger, C. (1989). 'An Experiment is When You Try It and See if It Works': A Study of Grade 7 Students' Understanding of The Construction of Scientific Knowledge. *International Journal of Science Education*, 11(5), 514-529.
- Delen, Y., & Keserciodlu, T. (2012). How Middle School Students' Science Process Skills Affected by Turkey's National Curriculum Change?. *Journal of Turkish Science Education*, 9(4), 7-14.
- Duruka, U., Akgüna, A., Doganb, C., & Gülsuyuc, F. (2017). Examining the Learning Outcomes Included in the Turkish Science Curriculum in Terms of Science Process Skills: A Document Analysis with Standards-Based Assessment. *International Journal of Environmental and Science Education*, 2(1), 10-18.
- Feyzioglu, E. Y., & Tatar, N. (2012). An Analysis of The Activities in Elementary Science and Technology Textbooks According to Science Process Skills and Structural Characteristics. *Eğitim Ve Bilim-Education and Science*, 37(164), 108-125.
- Foulds, W., & Rowe, J. (1996). The Enhancement of Science Process Skills in Primary Teacher Education Students. *Australian Journal of Teacher Education*, 21(1), 2-12



- Germann, P. J. (1994). Testing A Model of Science Process Skills Acquisition: An Interaction with Parents' Education, Preferred Language, Gender, Science Attitude, Cognitive Development, Academic Ability, and Biology Knowledge. *Journal of Research in Science Teaching*, 31(7), 749-783.
- Harlen, W. (1999). Purposes and Procedures for Assessing Science Process Skills. *Assessment in Education: Principles, Policy & Practice*, 6(1), 129-144.
- Hofstein, A., & Lunetta, V. N. (2004). The Laboratory in Science Education: Foundations for The Twenty-first Century. *Science Education*, 88(1), 28-54.
- Karamustafaoglu, S. (2011). Improving The Science Process Skills Ability of Prospective Science Teachers Using I Diagrams. *Eurasian Journal of Physics and Chemistry Education*, 3(1), 26-38.
- Kuhn, D., & Dean Jr, D. (2005). Is Developing Scientific Thinking All About Learning to Control Variables?. *Psychological Science*, 16(11), 866-870.
- Monhardt, L., & Monhardt, R. (2006). Creating A Context for The Learning of Science Process Skills Through Picture Books. *Early Childhood Education Journal*, 34(1), 67-71.
- Sinan, O., & Usak, M. (2011). Evaluating of Prospective Biology Teachers' Scientific Process Skills. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 8(15), 333-348.
- Özgelen, S. (2012). Students' Science Process Skills within A Cognitive Domain Framework. *Eurasia Journal of Mathematics, Science & Technology Education*, 8(4), 283-292.
- Öztürk, N., Tezel, Ö., & Acat, M. B. (2010). Science Process Skills Levels of Primary School Seventh Grade Students In Science and Technology Lesson. *Journal of Turkish Science Education*, 7(3), 15-19.
- Rani, S. A., Wiyatmo, Y., & Kustanto, H. (2017). Concept Attainment Worksheet to Enhance Concept Knowledge and Science Process Skills In Physics Instruction. *Jurnal Pendidikan IPA Indonesia*, 6(2), 326-334.
- Mohd, S. R., (2004). The Acquisition of Integrated Science Process Skills In A Web-Based Learning Environment. *Research in Science & Technological Education*, 22(1), 23-40.
- Sukarno, A. P., & Hamidah, I. (2013). The Profile of Science Process Skill (SPS) Student at Secondary High School (Case Study in Jambi). *International Journal of Scientific Engineering and Research (IJSER)*, 1, 79-83.
- Temiz, B. K., Tasar, M. F., & Tan, M. (2006). Development and Validation of A Multiple Format Test of Science Process Skills. *International Education Journal*, 7(7), 1007-1027.
- Usmeldi, U. (2016). The Development of Research-Based Physics Learning Model with Scientific Approach to Develop Students'scientific Processing Skill. *Jurnal Pendidikan IPA Indonesia*, 5(1), 134-139.



## ANALYSIS OF STUDENTS' CRITICAL THINKING SKILL OF MIDDLE SCHOOL THROUGH STEM EDUCATION PROJECT-BASED LEARNING

L. Mutakinati\*<sup>1</sup>, I. Anwari<sup>2</sup>, K. Yoshisuke<sup>3</sup>

<sup>1,2</sup>Graduate School of Science and Technology, Shizuoka University

<sup>3</sup>Department of Science Education, Shizuoka University

DOI: 10.15294/jpii.v7i1.10495

Accepted: December 26<sup>th</sup>, 2017. Approved: February 20<sup>th</sup>, 2018. Published: March 19<sup>th</sup>, 2018

### ABSTRACT

This research is to investigate the students' critical thinking skill by using STEM education through Project Based Learning. The study applied descriptive research design. In these lessons, the participants were 160 first grade Japanese middle school students from four classes. They were divided into nine groups each class. The instruments are worksheets to explore students' initial knowledge about how to clean up wastewater and critical thinking processes. The worksheet consists of the designing solution, and understanding of concepts to identify critical thinking based on purpose and question, selection of information, assumption, and point of view the solution, and implication. Students were asked to design tools to clean up the wastewater. Students were given more than one chance to design the best product for wastewater treatment. The lessons consist of six lessons. The first lesson is the introduction of colloid, solution, and suspension, and discussion about wastewater. The second lesson to the fourth lesson was finding solutions and designing products. The fifth lesson was to watch a video of wastewater treatments in Japan and to optimize the solutions or products. The last lesson was to make a conclusion, to exchange presentations, and to develop discussion. Implementation of STEM education can be seen from the students' solutions, some students used biology or chemistry or physics or combination concept and Mathematics to design solution (technology) for treatment of wastewater. The result showed that the mean score of students' critical thinking skill was 2.82. The students' critical thinking skill was categorized as advanced thinker: 41.6%, practicing thinker: 30.6%, beginning thinker: 25%, and challenged thinker: 2.8%. And the category for students' critical thinking was practicing thinker. Practicing thinker is a stage of critical thinking development, they have enough skill in thinking to critique their own plan for systematic practice, and to construct a realistic critique of their powers of thought to solve the contextual problem.

© 2018 Science Education Study Program FMIPA UNNES Semarang

**Keywords:** STEM, Project-Based Learning, Critical Thinking

### INTRODUCTION

According to predictions, the job in STEM (Science, Technology, Engineering, and Mathematics) sectors will increase in the next decade more than jobs in other sectors. Therefore, the importance of STEM education has been realized by academia, government, society, and in-

dustry (Bybee, 2010). In the future, the students possibly do not work based on their educational background. The role of education as basic-career advancement has been aimed in the international setting (Mayo, 2009). Therefore, STEM education could be a way to bridge the gap between education and required workplace of 21st-century skills.

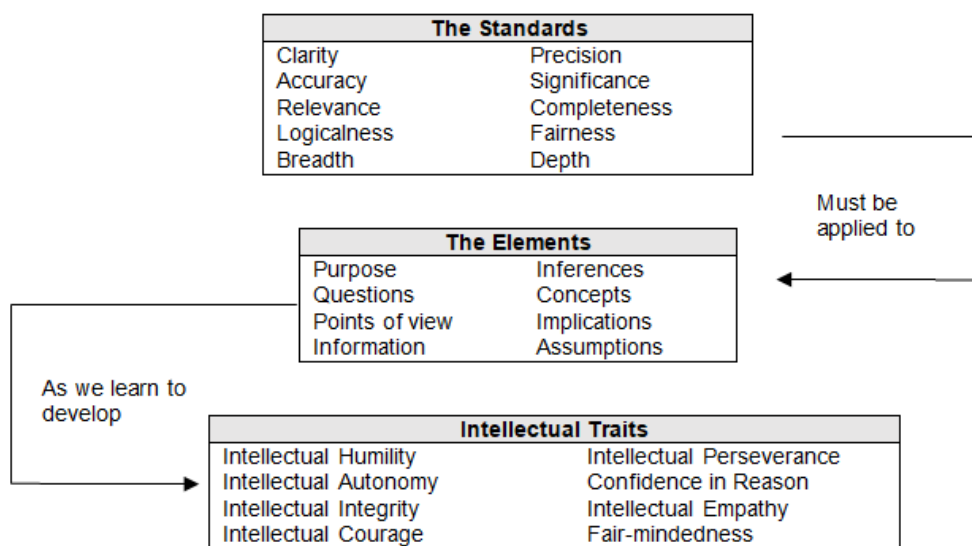
According to data from the United State Department of Labor, the importance of STEM

\*Correspondence Address:  
E-mail: mutakinati@yahoo.com

skills are problem-solving skills (ill-defined problem), system skills, technology and engineering skills, and time, resource, and knowledge management skills (Kuenzi, 2008; Jang, 2016,). In the 21st century, scientific experiments are not sufficient to improve students' 21st-century skills, but how to apply scientific concepts to design the technologies or products and solving problems is also required. The change of human life will be accompanied by the evolution of technology. Therefore, students have to be prepared for the future challenges. Scientific inquiry, scientific practices, and engineering practices are required to encourage students to be a citizen who can adapt to face new conditions and problems (Bybee, 2013).

In addition, students create and present project-based assignments outside of the traditional classroom (teacher-centered delivery of instruction to classes of students who are the receivers of information) that connect to what they learn to real world applications. *STEM Project Based Learning (PBL)* in school motivated low performing students to be more interested in studying hard in STEM fields and decrease the achievement gap (Breiner et al., 2012).

Critical thinking is one of the most important real-life skills. Where in Next Generation Science Standard (NGSS) mentioned that critical thinking and communication skills must be possessed by students for their future. Critical thinking is analyzing and evaluating thinking with a view to improve it, in another words, self-directed, self-disciplined, self-monitored, and self-corrective thinking. In critical thinking, there are six stages consist of unreflective thinker, challenged thinker, beginning thinker, practicing thinker, advanced thinking, and master thinker (Paul & Elder, 2008). Critical thinking refers to an ability to analyze information, to determine the relevance of information gathered and then to interpret it in solving the problems. It requires high-level thinking; involves the process of analysis, evaluation, reasonableness, and reflection (Jeevanantham, 2005). According to Paul & Elder (2008), there are 8 elements of thought namely: purpose, questions at issue, information, interpretations and inferences, concepts, assumptions, implications and consequences, and point of view. The intellectual Standards describe the criteria used to evaluate the quality of the critical thinking.



**Figure 1.** The Paul-Elder Framework for Critical Thinking (Paul-Elder, 2009).

Some researchers have reported that students in PBL taught classrooms improved critical thinking and problem-solving skills. Another researcher has also found that PBL has been a successful method of teaching 21st-century skills. Furthermore, students also have shown more initiative by utilizing resources and revising works, also students' behaviors were uncharacteristic

before they were immersed in the PBL-instructed classes (Baron, et al., 1998).

Human beings can survive up to three weeks without food. In contrast, a lack of water is fatal within three to four days. This grim fact makes water disaster preparedness vital. Flooding, severe weather, earthquakes, and civil unrest can all interrupt public water delivery or introduce

dangerously contaminates into your drinking supplies. Private well water may also be affected by floods, chemical spills, or similar catastrophes. A carefully thought out water disaster preparedness plan saves many lives.

Human beings can survive up to three weeks without food. In contrast, a lack of water is fatal within three to four days. This grim fact makes water disaster preparedness vital. Flooding, severe weather, earthquakes, and civil unrest can all interrupt public water delivery or introduce dangerously contaminates into your drinking supplies. Private well water may also be affected by floods, chemical spills, or similar catastrophes. A carefully thought out water disaster preparedness plan saves many lives.

The research goals are to investigate students' critical thinking in STEM education through Project Based Learning that makes students more aware of the needs for clean water in the future (Stohlmann et al., 2012). Moreover, this research is not only to improve students' awareness and understanding of the needs of clean water, but also to improve students' critical thinking skills in their daily life (Gonzalez & Kuenzi, 2012). Therefore, students can apply what they learned at school to daily life problems or issues. The problem in this research is how students' critical thinking skills are developed through STEM education Project Based Learning.

## METHODS

The study applied descriptive research design. Descriptive research is used to obtain information concerning the current status of the phenomena to describe the condition with respect to variables or conditions in a situation. Descriptive studies have an important role in educational research, they have greatly increased our knowledge about what happens in schools (Fraenkel & Wallen, 2006). Descriptive research can be either quantitative or qualitative. It can involve collections of quantitative information that can be tabulated along a continuum in numerical forms, such as scores on a test or the number of times a person chooses to use a certain feature

of a multimedia program, or it can describe categories of information such as gender or patterns of interaction when using technology in a group situation (Knupfer & Hilary, 1966).

The participants were 160 first grade Japanese middle school students from four classes. They were divided into nine groups in each class. The instruments were worksheets to explore students' critical thinking skills how to clean up wastewater and problem-solving processes. Besides, the instruments were wastewater, filter paper, beaker glass, plastic bottles, litmus paper, and some materials or tools which needed by students (Williams, 2011). Therefore, students had to think the materials in order to solve problems.

In these lessons, students did not only wrote worksheets but also designed tools to clean up the wastewater. Students were given more than one chance to design the best product for wastewater treatment (Museus et al., 2011). The lessons consist of six lessons, the first lesson was the introduction of colloid, solution, and suspension, and discussion about wastewater. From the second lesson to the fourth lesson were to find solutions and design products. The fifth lesson was the video of wastewater treatment in Japan and optimize the solutions or products. The last lesson was to make a conclusion, presentation, and discussion. The lessons were started by the explanation of different solution and colloid. Furthermore, the illustration of a problem about the need of wastewater system in our city to conserve the sea was displayed. Then, students were asked to find solutions to clean wastewater (Milgram, 2011).

The data were collected by worksheets and observation sheets during the lessons. Then, data were analyzed using critical thinking rubric that designed by (Paul & Elder, 2009, Uttal et al., 2012). Paul & Elder critical thinking framework was one of the frameworks used by some researchers to analyze critical thinking because this framework was general for engineering, natural science, social science, and linguistics. The collected data were analyzed using ANOVA in order to see different of critical thinking of each class.

**Table 1.** Critical Thinking Rubric (based on the Paul-Elder critical thinking framework)

Dimension	Score			
	4	3	2	1
Purpose and question	Clearly identify the purpose including all complexities of relevant questions.	Clearly identify the purpose including some complexities of relevant questions.	Identify the purpose including irrelevant and/or insufficient questions.	An unclear purpose that does not includes questions.

Information	Accurate, complete information that is supported by relevant evidence.	Accurate, mostly complete information that is supported by evidence.	Accurate, but incomplete information that is not supported by evidence.	Inaccurate, incomplete information that is not supported by evidence.
Assumption and point of view	Complete, fair presentation of all relevant assumptions and points of view.	Complete, fair presentation of some relevant assumptions and points of view.	Simplistic presentation that ignores relevant assumptions and points of view.	Incomplete presentation that ignores relevant assumption and points of view
Implications and consequences	Clearly articulates significant, logical implications and consequences based on relevant evidence	Clearly articulates some implications and consequences based on evidence.	Articulates insignificant or illogical implications and consequences that are not supported by evidence.	Fails to recognize to generates invalid implications and consequences based on irrelevant evidence

Scores from critical thinking rubric were compared with criteria of critical thinking development based on stages of critical thinking development (Table 2)

**Table 2.** Scoring of Critical Thinking Development Stages (Paul and Elder, 2009)

Criteria of score:	3.51	-	4.0	:	Master Thinker
	3.11	-	3.50	:	Advanced Thinker
	2.41	-	3.10	:	Practicing Thinker
	1.71	-	2.40	:	Beginning Thinker
	1.01	-	1.70	:	Challenged Thinker
	0	-	1.0	:	Unreflective Thinker

**RESULTS AND DISCUSSION**

**STEM Education through Project Based Learning**

STEM learning through Project Based Learning was developed by NGSS (Next Generation Science Standard) framework. In this study, the lessons consisted of six lessons, the first lesson was the introduction of colloid, solution,

and suspension, and discussion about wastewater. The second lesson to the fourth lesson was to find solutions and design products. The fifth lesson was to watch the video of wastewater treatment in Japan and optimize the solutions or products. The last lesson was to make a conclusion, presentation, and discussion. Each learning process was described in the following table 3.

**Table 3.** STEM Lessons

Activity	Crosscutting Concepts	Scientific and Engineering Practices (NGSS Framework)	Disciplinary Core Ideas
<b>First Lesson</b>			
Introduction of the theme of lessons and dividing the groups. (9 groups)			

Provide students to mention examples of solid, liquid, and gas (state of matter) in their daily life. <b>(Physics)</b>	Molecules pattern of solid, liquid, and gas. (CCs 1)	Asking questions and defining problems. (SEPs 1)	<b>Structure and Properties of Matter</b> The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter. (PSs 1.A)
Students observe the demonstration and determine the colloid. <b>(Chemistry)</b>	Pattern, Cause and Effect, Scale. (CCs 1, CCs 2, CCs 3)	Asking questions and defining problems. (SEPs 1) Engaging in argument from evidence. (SEPs 7)	
Teacher introduce wastewater treatment plant/cleaning water system and asks students to find any information about how to clean wastewater. <b>Science</b> -discussing water pollution and which science concept is suitable to solved the problem. <b>Technology</b> -the solution <b>Engineering</b> -process designed solution. <b>Mathematics</b> -measure of amount the material.	The matter is conserved because atoms are conserved in physical and chemical processes. (CCs 5)	Constructing explanations and design solutions. (SEPs 6)	Type of Interaction Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (PSs 2.B)
Students search information in internet, books, and so on.			

### Second, Third, and Fourth Lesson

Students design wastewater treatment system. Students determine what they need to clean wastewater. Students check water clarity by their eyes. <b>(Science, Technology, Engineering, and Mathematics)</b> . Students check pH before and after cleaning processes. Students redesign the wastewater treatment system. <b>(Science, Technology, Engineering, and Mathematics)</b> .	Influence of science, engineering, and technology on society and the natural world. (CCs 7)	Asking questions and defining problems. (SEPs 1) Developing and using models. (SEPs 2) Planning and carrying out investigations. (SEPs 3) Analyzing and interpreting data. (SEPs 4) Using mathematics and computational thinking. (SEPs 5) Constructing explanation and designing solutions. (SEPs 6) Engaging in argument from evidence. (SEPs 7)	Defining and delimiting engineering problems. (ETSs 1.A) Developing possible solutions. (ETSs 1.B) Optimizing the design solution. (ETSs 1.C)
---	---	--	---

---

### Fifth Lesson

<p>Students watch the video about wastewater treatment plant.</p> <p>Students redesign wastewater treatment by drawing or if the time is available, students can redesign their prototype. <b>(Science, Technology, Engineering, and Mathematics).</b></p>	<p>Influence of science, engineering, and technology on society and the natural world. (CCs 7)</p>	<p>Developing and using models. (SEPs 2)</p> <p>Planning and carrying out investigations. (SEPs 3)</p> <p>Analyzing and interpreting data. (SEPs 4)</p> <p>Using mathematics and computational thinking. (SEPs 5)</p> <p>Constructing explanation and designing solutions. (SEPs 6)</p> <p>Engaging in argument from evidence. (SEPs 7)</p>	<p>Defining and delimiting engineering problems. (ETSs 1.A)</p> <p>Developing possible solutions. (ETSs 1.B)</p> <p>Optimizing the design solution. (ETSs 1.C)</p>
--	--	---	--

### Sixth Lesson

<p>Students present and explain their prototype of wastewater treatment system (concept, before and after treatment, and material used). <b>(Science, Technology, Engineering, and Mathematics).</b></p>	<p>Influence of science, engineering, and technology on society and the natural world. (CCs 7)</p>	<p>Obtaining, evaluating, and communicating information. (SEPs 8)</p>	<p>Defining and delimiting engineering problems. (ETSs 1.A)</p> <p>Developing possible solutions. (ETSs 1.B)</p> <p>Optimizing the design solution. (ETSs 1.C)</p>
--	--	---	--

---

### Analysis of Students' Critical Thinking

Collected data from the worksheets involved design solutions, results, and conclusions. The problems defined by students was almost same, which was 'how to clean wastewater before moving to the sea because if the sea dirty, it would damage the environment'. Some examples of students' design solution can be seen in table 4. Most of the students had ideas about distillation and filtering system to clean the wastewater.

According to students' worksheets, some of the groups cleaned wastewater using simple distillation system or boiling. However, students realized that boiling consumed more energy and could not be an efficient solution. In this case, students evaluated their solution, it meant indicating that they had critical thinking skills. Furthermore, students used euglena to clean wastewater. Unfortunately, the results were unexpected, wastewater was still dirty. Based on their experiment results, they thought that distillation method could clean wastewater and use Euglena would not contaminate the environment. Final-

ly, students concluded that the combination of distillation and euglena would be an effective, efficient, and environmentally friendly solution. According to these statements, students were still lack of logical thinking and made a conclusion from the data. Distillation used heat for boiling the water, so it could not be an efficient solution.

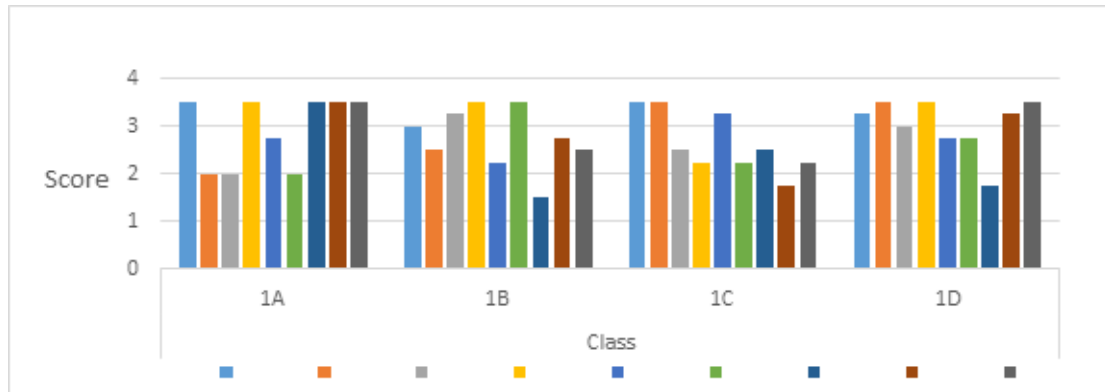
Another one of the samples of students' solution was evaporation. They provide 3 samples of wastewater and each sample was boiled in different length time. Their thinking was a similar researcher and they tried to investigate the result based on length time of boiling. However, they did the experiments in an opened condition. So, the clean water would go to atmosphere. Even though 15 minutes boiling showed the cleanest result than others pH of wastewater was most acidic than others. According to this, 15 minutes boiled sample was not fresh water, because the range of pH was too large. If this acid water goes es to the sea, it would make the sea be acidic. They did not analyze and evaluate the data, it means that they lack in critical thinking skill.

**Table 4.** Students` Design Solution and Classifying Stages of Critical Thinking.

Design Solution	Result	Conclusion	Stage CT
<p>Boiling wastewater in an isolated system will keep water in the system.</p> <p>S: physic T: evaporation kit E: design evaporation kit from beaker glasses (small and big). M : not used</p>	<p>Dirty water became clean, but it consumes much time.</p>	<p>Boiling water is effective method to clean water.</p>	<p>Challenged Thinker (Lower Thinker)</p>
<p>Biological</p> <p>Using water (microorganism) from turtle pond (surface, middle, bottom), and leave for one day, after that stir the wastewater. Avoid the sunlight.</p> <p>S: biology and physic T: cleaning system using micro organism E: design bath of biological cleaning system. M: not used</p>	<p>No significant difference of each sample, but after being stirred, the sample became little clean.</p>	<p>Stirring was needed for better result. Pond water did not work to clean wastewater. Perhaps, there no microorganism who can clean the water.</p>	<p>Beginning Thinker (Average Thinker)</p>
<p>Physical filtering</p> <p>1<sup>st</sup> experiment used filter paper, stone, leaf, and charcoal. 2<sup>nd</sup> experiment did not use leaf. 3<sup>rd</sup> experiment did not use filter paper. S: physic T: filtering kit E: design filtering system by various materials. M: not used</p>	<p>1<sup>st</sup> experiment: the water was clean. 2<sup>nd</sup> experiment: the result was not different from 1<sup>st</sup> experiment. 3<sup>rd</sup> experiment: after two times filtering, the water became clean.</p>	<p>The leaf does not the role of the cleaning system, but filter paper has it.</p>	<p>Practicing Thinker (Average Thinker)</p>
<p>Distillation</p> <p>Identify effectiveness based on volume of samples 10 ml, 20 ml, and 30 ml. Biological system (using euglena). Mix pond water and sample, and then store for a day. S: physic and biology T: distillation kit E: design distillation kit from tubes, pipe, and rubber stopper. M: calculate the volume of sample</p>	<p>Distillation: the water became clean, but consumed energy. Using Euglena: no change anything, but environmental friendly.</p>	<p>The combination of distillation and using euglena would become effective and environmental friendly solution.</p>	<p>Advanced Thinker (Higher Thinker)</p>



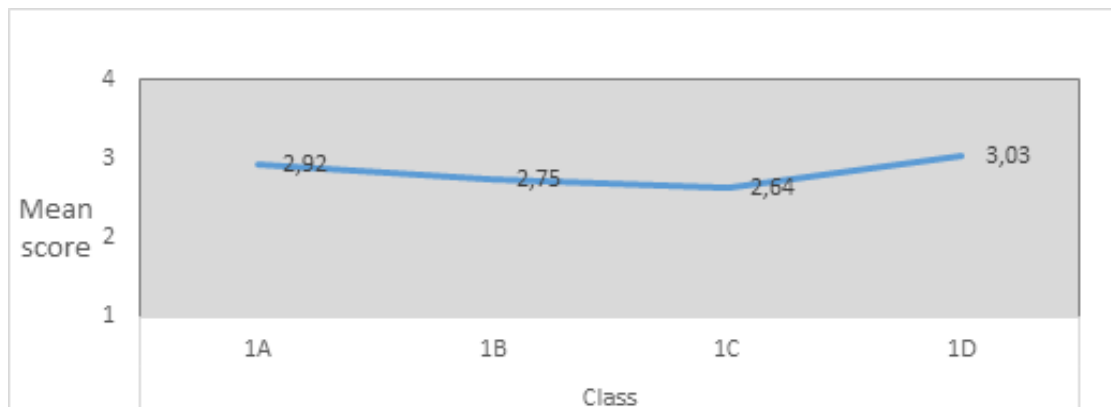
These worksheets were analyzed using critical thinking rubric (Table.1) and the result of critical thinking of each group in all classes is shown in figure 1.



**Figure 1.** Score of Critical Thinking

Based on measures Tukey test, the mean scores of critical thinking skill for each class can be compared in order to see a significant difference. The result shows that the mean critical thinking score for class 1A was 2.92 (SD 0.72); 1B was 2.75 (SD 0.65); 1C was 2.67 (SD 0.62); 1D

was 3.03 (SD 0.62), and mean score of critical thinking all of the students was 2.82. The highest students' critical thinking skill is class 1D, and the lowest is 1C. There was significant with the reports of the Tukey multiple comparisons for the critical thinking score.



**Figure 2.** Critical Thinking Skill's Mean Scores

**Table 5.** Tukey Multiple Comparison of Critical Thinking Score

(I) CLASS		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1A	1B	.16667	.30979	.949	-.6727	1.0060
	1C	.27778	.30979	.807	-.5615	1.1171
	1D	-.05556	.30979	.998	-.8949	.7838
1B	1A	-.16667	.30979	.949	-1.0060	.6727
	1C	.11111	.30979	.984	-.7282	.9504
	1D	-.22222	.30979	.889	-1.0615	.6171

1C	1A	-.27778	.30979	.807	-1.1171	.5615
	1B	-.11111	.30979	.984	-.9504	.7282
	1D	-.33333	.30979	.706	-1.1727	.5060
1D	1A	.05556	.30979	.998	-.7838	.8949
	1B	.22222	.30979	.889	-.6171	1.0615
	1C	.33333	.30979	.706	-.5060	1.1727

In order to determine of q score of Tukey test, q calculate is mean difference divided by the standard error. Furthermore, q critical can see from table q score in which k (number of class) is 2, df (number of data – k) is 16. The calculation to determine the significance of difference can be seen in table 6. According to the calculation of

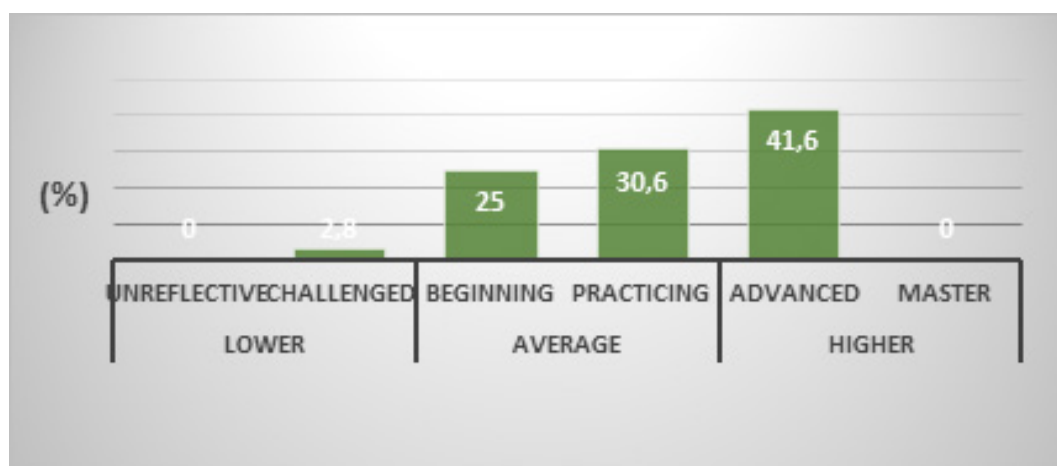
Tukey test, the score of critical thinking skill of each class shows no significant among students' performance, because of  $q_{cal}$  is lower than  $q_{criti-cal}$  (Hochberg, 1987). It means that the learning processes of each class were the same, so critical thinking skill of students in each class no gap at all.

**Table 6.** Significance Difference of Each Class

Class	Q calculate	Q critical (alpha = 0.05)	hypothesis
1A – 1B	0.539	3.00	No different significantly
1A – 1C	0.897	3.00	No different significantly
1A – 1D	0.181	3.00	No different significantly
1B – 1C	0.358	3.00	No different significantly
1B – 1D	0.716	3.00	No different significantly
1C – 1D	1.074	3.00	No different significantly

Critical thinking score compared d with criteria of critical thinking development based on the stage of critical thinking development (Table 2.). Categories of students' critical thinking skill were an advanced thinker (41.6%), practicing thinker (30.6%), beginning thinker (25%), and

challenged thinker (2.8%). In simple word, challenged thinker included in lower thinker, beginning and practicing thinker included in average thinker, and advanced thinker included in higher thinker (figure 3).



**Figure 3.** Stage of Critical Thinking (%)

Unreflective thinkers and challenged thinkers included in lower thinker. The finding indicates that only 1 group had lower thinker stage of critical thinking. Lower thinkers had very limited skills in thinking, they only focus ed on one solution, and they did not try to give better solutions. As shown in Table 4, lower thinkers' design solution was simple isolated cleaning wastewater isolated evaporation system kit from beaker glasses. There was no separation between clean water and wastewater. The lower thinker group conducted one experiment only and they did not evaluate at all. Whereas learning activities were conducted in 6 lessons, it was possible to evaluate their experiment. However, they may have developed a variety of skills in thinking without being aware of them, and these skills may serve as barriers to the development. At this stage of critical thinking with some implicit critical thinking abilities may deceive themselves easily into believing that their thinking was better than what actually was, they were making it more difficult to recognize the problems inherent in poor thinking (Paul & Elder, 2008).

Average thinkers have 2 stages of critical thinking, there were beginning thinker and average thinker. Thinkers at this stage had a sense of the habits which they needed to develop to take charge of their thinking. Base on Table 4, average thinkers' design solutions were cleaning wastewater system by filtering kit. They tried some experiments to get a better solution. This method was effective to clean water, but it was not efficient. In engineering solution, efficiency and effectiveness must be concerned. However, since average thinkers only began with to approach the improvements of their thinking in a systematic way. Average thinkers had enough skills in thinking to critique their own plan for systematic practices and to construct a realistic critique of their powers of thought (Paul & Elder, 2009). Furthermore, average thinkers had enough skills, to begin with regularly monitor their own thoughts. Thus they could effectively articulate the strengths and weaknesses of their thinking. Practicing thinkers could often recognize their own egocentric thinking as well as egocentric thinking on the part of others (Paul & Elder, 2008).

**Table 7.** T-test between Mean Scores Lower-Average-Higher Thinker

	t	df	Sig. (2-tailed) P <sub>value</sub> = ½ Sig	Test Value = 0		
				Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Score (lower-average)	25.092	19	.000	2.32500	2.1311	2.5189
Score (average-higher)	27.700	34	.000	2.85714	2.6475	3.0668

Advanced thinkers (higher thinker) regularly critiqued their own plan for systematic practices, and improve it thereby and had established good habits of thought which were "paying off". As shown in Table 4, higher thinkers' design solution was cleaning wastewater system by combining 2 methods, biological and distillation kit. They tried various methods and combined the methods to get best solutions. The combination of distillation and biological would become effective and environmentally friendly solutions. Based on these habits, advanced thinkers not only analyzed their thinking in all the significant domains of their lives but also had significant insights into problems at deeper levels of thought. While advanced thinkers were able to think well across the important dimensions of their lives, they were not yet able to think at a consistently high level across all of these dimensions. Advan-

ced thinkers had good general commands over their egocentric nature. They continually strived to be fair-minded and sometimes lapsed into egocentrism and reason in a one-sided way (Paul & Elder, 2008).

T-test was used to determine significant differences between mean score lower thinkers-average thinkers, and average thinkers-higher thinkers. Table 7 reports there are significant differences between mean lower thinkers and average thinkers (Pvalue< 0.05). Also, base on table 7, there are significant differences between mean average thinkers and higher thinkers (Pvalue< 0.05). Overall, the findings of differences between mean score lower thinker-average thinker-higher thinker suggested that STEM learning through Project Based Learning could differentiate between lower thinker, average thinker, and higher thinker.

## CONCLUSION

This study has achieved its objectives. The study aims to investigate students' critical thinking skill in STEM education through Project Based Learning. The result showed that mean score of students' critical thinking skills was 2.82. Percentages of students' critical thinking skill were the advanced thinker (higher thinker) 41.6%, practicing thinker (average thinker) 30.6%, beginning thinker (average thinker) 25%, and challenged thinker (lower thinker) 2.8%. And the category of students' critical thinking was the average thinker. Average thinker was a stage of critical thinking development, they have enough skill in thinking to critique their own plan for systematic practice, and to construct a realistic critique of their powers of thought.

The present study has some limitations that need to be taken into account when considering the study and contributions. The participants in this study were self-selected based on random distribution, there was no arrangement in the division of the groups. The division of group should consist of higher thinker who can be a leader to guide lower thinker.

## REFERENCES

- Barron, B. J., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., & Bransford, J. D. (1998). Doing with understanding: Lessons from research on problem-and project-based learning. *Journal of the Learning Sciences*, 7(3-4), 271-311.
- Breiner, J. M., Harkness, S. S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*, 112(1), 3-11.
- Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, 70(1), 30-35.
- Bybee, R. W. (2013). The case for STEM education: Challenges and opportunities. *National Science Teachers Association*.
- Capraro, R. M., Capraro, M. M., & Morgan, J. R. (Eds.). (2013). *STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach*. Springer Science & Business Media.
- Capraro, R. M., & Slough, S. W. (2013). Why PBL? Why STEM? Why now? An introduction to STEM project-based learning. In *STEM Project-Based Learning* (pp. 1-5). SensePublishers.
- Duran, M., & Sendag, S. (2012). A preliminary investigation into critical thinking skills of urban high school students: Role of an IT/STEM program. *Creative Education*, 3(2), 241.
- Fraenkel, J. R., & Wallen, N. E. (2003). How to design and evaluate research in education. *McGraw-Hill Higher Education*.
- Gonzalez, H. B., & Kuenzi, J. J. (2012). Science, technology, engineering, and mathematics (STEM) education: A primer. *Congressional Research Service, Library of Congress*.
- Husamah, H. (2015). Blended project based learning: thinking skills of new students of biology education department (environmental sustainability perspective). *Jurnal Pendidikan IPA Indonesia*, 4(2).
- Hochberg, Y., & Tamhane, A. C. (2009). Multiple comparison procedures.
- Jang, H. (2016). Identifying 21st century STEM competencies using workplace data. *Journal of Science Education and Technology*, 25(2), 284-301.
- Jeevanantham, L. S. (2005). Why teach critical thinking?. *Africa education review*, 2(1), 118-129.
- Kertil, M., & Gurel, C. (2016). Mathematical modeling: A bridge to STEM education. *International Journal of Education in Mathematics, Science and Technology*, 4(1), 44-55.
- Kuenzi, J. J. (2008). Science, technology, engineering, and mathematics (STEM) education: *Background, federal policy, and legislative action*.
- Kumano, Yoshisuke. (2014). The characteristics of STEM education in the US and possible implementation models for Japanese contexts: Examining the data from teacher training and model STEM activities. *The 2<sup>nd</sup> International Science, Mathematics and Technology Education Conference 7-9 November, 2014*, The Ambassador Hotel, Bangkok, Thailand.
- Khasanah, A. N., Widoretno, S., & Sajidan, S. (2017). Effectiveness of Critical Thinking Indicator-Based Module in Empowering Student's Learning Outcome in Respiratory System Study Material. *Jurnal Pendidikan IPA Indonesia*, 6(1), 16-25
- Lund, Stephanie, (2016). *Making learning authentic: an educational case study describing student engagement and motivation in a project-based learning environment*. Arizona State University.
- Mayo, M. J. (2009). Video games: A route to large-scale STEM education?. *Science*, 323(5910), 79-82.
- Mergendoller, J. R., Maxwell, N. L., & Bellisimo, Y. (2006). The effectiveness of problem-based instruction: A comparative study of instructional methods and student characteristics. *Interdisciplinary Journal of Problem-based Learning*, 1(2), 5-12.
- Milgram, D. (2011). How to recruit women and girls to the science, technology, engineering, and math (STEM) classroom. *Technology and engineering teacher*, 71(3), 4-11.
- Museus, S. D., Palmer, R. T., Davis, R. J., & Maramba, D. C. (2011). Special Issue: Racial and Ethnic Minority Students' Success in STEM Education. *ASHE Higher Education Report*, 36(6), 1-140.

- National Research Council. (2013). Monitoring progress toward successful k-12 stem education: a nation advancing. *National Academies Press*.
- N.N Knupfer, & Hilary McLellan. (1996). Computers in education: achieving equitable access and use. *Journal of Research on Computing in Education* 24(2), 22-32.
- Paul, R. W., & Elder, L. (2009). The miniature guide to critical thinking concepts & tools (6<sup>th</sup>ed). *CA: The Foundation for Critical Thinking*.
- Paul, R. W., & Elder, L. (2008). The thinkers' guide to engineering reasoning (2<sup>nd</sup>ed). *CA: The Foundation for Critical Thinking*.
- Putra, P. D. A., & Iqbal, M. (2016). Implementation of serious games inspired by baluran national park to improve students' critical thinking ability. *Jurnal Pendidikan IPA Indonesia*, 5(1), 101-108.
- Ralston, P. A., & Bays, C. L. (2013). Enhancing critical thinking across the undergraduate experience: an exemplar from engineering. *American Journal of Engineering Education*, 4(2), 119.
- Pratiwi, Y. N., Rahayu, S., & Fajaroh, F. (2016). Socio-scientific Issues (ssi) in reaction rates topic and its effect on the critical thinking skills of high school students. *Jurnal Pendidikan IPA Indonesia*, 5(2), 23-30.
- Rodzalan, S. A., & Saat, M. M. (2015). The Perception of Critical Thinking and Problem Solving Skill among Malaysian Undergraduate Students. *Procedia-Social and Behavioral Sciences*, 172, 725-732.
- Laboy-Rush, D. (2011). Integrated STEM education through project-based learning. *Learning*.
- Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER)*, 2(1), 4.
- Sumarni, W., Wardani, S., Sudarmin, S., & Gupitasari, D. N. (2016). Project Based Learning (PBL) to improve psychomotoric skills: a classroom action research. *Jurnal Pendidikan IPA Indonesia*, 5(2), 31-40.
- Suwono, H., Pratiwi, H. E., Susanto, H., & Susilo, H. (2017). Enhancement of Students' Biological Literacy and Critical Thinking of Biology through Socio-Biological Case-Based Learning. *Jurnal Pendidikan IPA Indonesia*, 6(2), 213-220.
- Usmeldi, U., Amini, R., & Trisna, S. (2017). The Development of Research-Based Learning Model with Science, Environment, Technology, and Society Approaches to Improve Critical Thinking of Students. *Jurnal Pendidikan IPA Indonesia*, 6(2), 318-325.
- Uttal, D. H., & Cohen, C. A. (2012). 4 Spatial Thinking and STEM Education: When, Why, and How?. *Psychology of learning and motivation-Advances in research and theory*, 57, 147.
- Vasquez, Jo Anne. (2014). Developing STEM site-based teacher and administrator leadership. *Exemplary STEM programs: designs for success*. National Science Teachers Association.
- Wardani, S., Lindawati, L., & Kusuma, S. B. W. (2017). The Development of Inquiry by Using Android-System-Based Chemistry Board Game to Improve Learning Outcome and Critical Thinking Ability. *Jurnal Pendidikan IPA Indonesia*, 6(2), 196-205.
- Williams, J. (2011). STEM education: Proceed with caution. *Design and Technology Education: An International Journal*, 16(1), 12-32.



## LEARNING EXPERIENCE OF PRE-SERVICE PHYSICS TEACHERS IN DEVELOPING SIMPLE PROJECT LOADED BY LIFE SKILLS

Susilawati\*<sup>1</sup>, Wijayanto<sup>2</sup>, N. Khoiri<sup>3</sup>, Masturi<sup>4</sup>, S. Xaphakdy<sup>5</sup>

<sup>1,2,3</sup>Physics Education Department, University of PGRI Semarang, Indonesia

<sup>4</sup>Physics Department, State University of Semarang, Indonesia

<sup>5</sup>Academic Affairs Office Division of Curriculum Development and Management, National University of Laos

DOI: 10.15294/jpii.v7i1.10889

Accepted: November 27<sup>th</sup>, 2017. Approved: March 6<sup>th</sup>, 2018. Published: March 19<sup>th</sup>, 2018

### ABSTRACT

This research aims to reveal the experience profile of future Physics teachers in developing simple multi-loaded life skill project. The research method used was a descriptive method with 62 future Physics teachers as the research subject. Based on observations, interviews, and questionnaires, it was drawn descriptions of the future teachers' experiences in developing a simple project. The future teachers were assessed based on some Physics indicators such as project design, project creation, data collection, data analysis, and creativity. The results of the project preparation descriptions obtained by the experience data of future Physics teachers indicate the highest score of 4.8 (96%) on the indicator of schedule making, while the lowest score was 2.9 (58%) on the indicators of formulating the product benefits, preparing the feasibility analysis and analyzing the environmental impact. The results show that future Physics teachers got the highest score of 4.6 (93%) on data adjustment for experimental purposes indicator, and the lowest score of 2.8 (55%) on designing tools and materials indicator. Based on the Physics props trial, it was obtained the highest score of 4.5 (89%) on the indicator of analyzing the baseline data, while the lowest score of 2.9 (58%) was on the variation test variables. Positive feedback about time-management in completing the project, the ability to identify the topic of the project, the ability to find ideas to support the completion of the project, the ability to test the tools, and the ability to make progress reports on project completion were derived from the interviews. The highest score of students' responses to project completion was 4.8 (95%) on the second data collection indicator and the lowest was 3.2 (64%) on the instrument material design indicator.

© 2018 Science Education Study Program FMIPA UNNES Semarang

Keywords: Simple Projects, Multi life skills.

### INTRODUCTION

The academic competence of pre-service Physics teachers has been categorized as 'good' based on knowledge aspect. This can be observed in basic Physics practices for basic concepts of mechanics, fluids, and electricity in the academic year 2013/2014 until 2015/2016. It turned out that during the practicums, future Physics teachers were not able to connect, explore and

construct the mastery of concepts as a learning experience during the lectures. In fact, these abilities are needed to support prospective Physics teachers to be professionals (Adams & Wieman, 2015; Docktor & Mestre, 2014; Estella, 2016).

The quality of future teachers includes the concept mastery that cannot be separated from the learning process they experienced (Ceberio, et al., 2016; Haji & Safitri, 2015; Khaeroningtyas, et al., 2016). Physics learning for future teachers

\*Correspondence Address

E-mail: susilawati@upgris.ac.id

should meet the following characteristics: (1) future teachers should be prepared to teach at the school level; (2) concrete experiences serve as the foundation for teaching specific concepts; (3) the learning process should begin with an Open-ended research in the laboratory; (4) learning should be designed to help future teachers think critically about the materials they are studying; (5) teaching materials for prospective teachers should be directed to build awareness of the conceptual difficulties that students may encounter later (Putra, et al., 2016; Sumarni, et al., 2016; Supriyanti, et al., 2015).

Basic Physics mastery is essential for future teachers. However, the conceptual learning model that begins with direct involvement through researches in laboratories is not popularly applied. There is no attempt to engage students in identifying and resolving misunderstandings that students might have. Moreover, it is uncommon to present Physics in order to achieve Physics competence as the main objective.

Providing knowledge and skills for future teachers will broaden their mind and develop learning awareness, resulting in students' eagerness to learn. This indicates that future teachers should practice cultivating students' creativity in conducting scientific activities so that the learning and evaluation process will be effective, efficient, challenging, and motivational (Cibik & Yalcin, 2011; Ozdamli, 2011; Nazila & Reza, 2011; Turk, et al., 2015; Hande, et al., 2015). Hence, teachers should adopt various methods, strategies, and models of learning so that learning becomes more interesting. One of the teaching methods that can be used is the project-based method.

The project-based method gives students the opportunity to manage their own problems. This kind of method can be done in 4 stages namely the stage of planning, implementing, assessing and revising. These stages are done by students to complete the project tasks. Project tasks provide a fun and challenging experience for students, help them to increase their experience, knowledge, and creativity. In implementing a project, students should be able to cooperate with friends, help each other and complement each other to complete the task. These would train students' social relationships and solidarity.

Project assignment results can be observed directly and enable students to communicate scientifically the task completion process. This project-based method fosters students' curiosity to learn more and make them be more creative. The learning steps using the project method include (1) exploration, by addressing a simple

question, providing a brief explanation and a small illustration to measure students' knowledge on the optical instrument; (2) presentation that explains the content of the materials in the learning process; (3) assimilation, by providing information or facts to fill an urgent subject. This challenges students to find sources that present facts and information related to project completion; (4) collecting data, facts, and information by classifying data, processing data and drawing conclusions. The ability to think and analyze the data is very important at this stage; and (5) assignment in the form of a presentation about students' findings, either verbally or in writing. This stage trains students to review the subject matter by applying the knowledge and experience possessed by them. (Yerushalmi, 2014; Yu, Fan & Lin, 2015; Balliet, et al., 2015).

Special-skill teachers are required in implementing project-based method regarding the detailed project method, operational standard of the procedures, and teaching materials. The use of project-based method in Physics learning takes a long time involving students either individually or classically. The assignments are given gradually, starting from the easiest. The project assignment results are monitored continuously. The holistic analysis method is used to evaluate the project results. While the project itself is conducted starting from collecting information and integrating it with new information, students' experiences and students' real activities. Project-based learning requires a comprehensive learning approach. The assignments in the project-based method are designed for students to investigate authentic problems which deepen students' comprehension on a subject topic and help them perform other meaningful tasks.

This approach introduces students to work independently in constructing products. In project-based learning, students are not only given recitation or complex but realistic projects, but also adequate assistance in order to complete the task. In addition, the implementation of this method encourages students' creativity, independence, responsibility, critical and analytical thinking. Project-based learning is inspired by constructivist learning theory. This theory builds on students' own knowledge in real-life experience. In terms of technology, project-based learning can be viewed as a learning approach that is close to the learning environment, which encourages teachers to construct knowledge and skills through direct experience.

Projects in project-based learning build on teachers' ideas as an alternative form of solving

specific, real problems. This suggests that project-based learning has the potential to deepen conceptual and procedural knowledge. Teachers direct the project and control students' ideas and interpretations in learning, learn how to conduct and express arguments on the projects. The characteristics of project-based learning have the potential to provide a more engaging and meaningful learning experience. The purpose of this research is to get the experience of Physics prospective teachers in developing a simple project in the form of Physics props. The results of this study outline the steps taken by prospective Physics teachers, starting from the project planning stage, project implementation, product testing, and project evaluation. These stages are divided into five indicators of Physics prospective teacher skills, among others; designing a project, creating a project, performing data analysis and bringing about creativity. In addition, the results of this study provide a description of learning resources used by future Physics teachers to develop a simple project.

## METHODS

This research involved future teachers to design a simple project that produces Physics props for high school level. The developed simple project deals with the concepts of mechanics, fluids, optics, and electricity. Purposive random sampling was used in selecting research samples. The total samples were 62 future Physics teacher of the 2016-2017 academic year at Universitas PGRI Semarang. There were 15 males and 47 females. The samples were divided into 2 large groups. Group 1 consisted of 7 small groups and group 2 consisted of 8 small groups. Each small group consisted of four to five people who have their respective duties.

The data collection tools used were observation sheets and questionnaires. The observation sheets included 4 stages; observation, planning, project implementation, testing, and evaluation. Each observation step consisted of 10 items of observation (Fraenkel & Wallen, 1993). The observation sheets used a 5-point Likert scale with 5 indicators from a positive statement to a negative

statement. Interviews were conducted to know the progress of students' projects; the interviews were done in 6 stages according to the students' progress report. Questionnaires were given to get feedback about experiences they have gained in developing simple projects and in using learning resources. Questionnaires were given on product testing activities. The questionnaire consisted of 10 statement items filled by 62 prospective Physics teachers for 20 minutes.

The obtained data were analyzed to give description and interpretation using data tabulation. Observational data were analyzed using independent t-test techniques. The results of the interviews employed the descriptive qualitative analysis. Questionnaire results were analyzed descriptively, while the percentage of students' positive answers was quantitatively calculated to get the maximum score.

## RESULTS AND DISCUSSION

The simple project development produced 15 packages of Physics props. The development achieved 70% and 30% improvement, which were obtained after repeated trials. The improvement rate was only 8% on the first attempt without repetition. The Physics props products are harmonic oscillation, automatic heat-conductivity gauge, collision displays, light diffraction, Conductivity Devices, Skewed Fields, Scale board of magnetic field, Refraction index tools, Conduction props, Measuring board, Fluid viscosity, BLDC motor, and Atwood plane.

Project-based learning has preparatory, implementation and evaluation activities. Therefore, the future teachers should design or create a project framework that is useful in providing the information and resources needed by the students in relation to the existing project. This supported the success of the project, helped students answering questions, activities, and completing their work. In addition, Future Physics teachers should perform their role well in analyzing and integrating learning materials. The results of the observations at the planning stage can be seen in table 1.

**Table 1.** Observation Results at the Planning Stage

Description of the Preparation	Min.	Max.	Mean	%	Std. Dev
Preparing project design	1	5	3.9	78	0.35
Formulating product benefits	1	5	2.9	58	0.27



Preparing a feasibility analysis	1	5	2.9	57	0.40
Creating an activity schedule	1	5	4.8	96	0.56
Preparing budget estimation	1	5	4.0	79	0.30
Arranging stages of the activity	1	5	4.9	97	0.45
Analyzing environmental impacts	1	5	2.9	58	0.30
Planning tools and materials	1	5	4.0	79	0.30
Planning the division of labor	1	5	4.0	79	0.30
Analyzing usage needs	1	5	3.9	79	0.40

The table shows that the highest score was on the indicator of creating the activity schedule and the lowest scores were on the indicators of formulating the benefits of the product, preparing the feasibility of the analysis and analyzing the environmental impact. The results of observations at the implementation stage can be seen in table 2.

**Table 2.** Observation Results at the Implementation Stage

Description of the Preparation	Min.	Max.	Mean	%	Std. Dev
Collection of tools and materials	1	5	3.9	78	0.4
Tools and materials design	1	5	2.8	55	0.4
Props Design	1	5	3.2	63	0.36
Props Design Variations	1	5	4.6	92	0.8
Initial data retrieval	1	5	3.9	79	0.56
Data adjustment for experimental purposes	1	5	4.6	93	0.54
Initial data analysis	1	5	3.3	66	0.73
Obtained data with other variations	1	5	4.0	80	0.63
Customization of data variations with experiment objectives	1	5	4.1	82	0.65
Analysis of data variations	1	5	4.0	80	0.50

The above table shows the project description obtained by the experience data of future Physics teachers with the highest score on the data adjustment for experimental purposes, and the lowest score on tools and materials design. The results of the observations in the test phase and evaluation of props can be seen in table 3.

**Table 3.** Observation Results at the Testing & Evaluation Stage

Description of the Preparation	Min.	Max.	Mean	%	Std. Dev
Preliminary data retrieval test	1	5	3.7	75	0.43
Trial variation variables	1	5	2.9	58	0.30
Testing of repeated data retrieval	1	5	3.1	61	0.25
Accurate measurements	1	5	4.4	87	0.93
Proof of experimental purpose	1	5	3.7	73	0.47

Results of initial data analysis	1	5	4.5	89	0.80
Results of variable measurement variation analysis	1	5	3.3	65	0.73
Results of repeated data analysis	1	5	3.7	73	0.54
Easy test tool	1	5	3.7	75	0.62
Recommended appliance repair	1	5	3.8	76	0.48

The results of experimental Physics test obtained by the experience data of future Physics teachers show the highest score on the indicator of analyzing the initial data, and the lowest sco-

re on the indicator of variable measurement variation analysis. The results of interviewing the project completion process can be seen in table 4.

**Table 4.** Interview Results for the Project Completion Process

Description	Statement
Ability to manage time to complete the project	We developed project schedules and set performance targets
Ability to identify project topics	We identified more than two submission project topics
Ability to find ideas to support the project	We found ideas as a test phase to support the completion of the project
Ability to test the tools	We did a test tool to get relevant data to the theory
Ability to make progress report on project completion	We made the progress report of project completion as a reference of improvement

The above table shows the interview results of the students on the project completion process. While the results of questionnaire res-

ponses of future Physics teacher to the project completion can be seen in table 5.

**Table 5.** Responses of Future Physics Teachers to the Project Completion

Description of the Preparation	Min.	Max.	Mean	%	Dev. Std.
The use of tools and materials	1	5	4.1	83	0.5
Designing tools and materials	1	5	3.2	64	0.8
Modification of props design	1	5	3.3	66	0.7
The first data retrieval analysis of the first data	1	5	4.6	92	0.8
The first data	1	5	3.9	79	0.6
The second data retrieval	1	5	4.8	95	0.6
Analysis of the second data	1	5	3.4	68	0.8
Creating charts from tabular data	1	5	3.9	78	0.6
Evaluation of tool making and data retrieval	1	5	4.1	82	0.7
Revision of props	1	5	4.4	82	0.5

The results of the students' responses to the project completion indicated the highest score on the second data collection indicator and the lowest score on the designing tools and materials indicator. Future Physics teachers worked on one individual project and one group project activity

in the classroom. They determined the activities and steps to be taken in accordance with the subtopic, planned the time allotment of all subtopics and saved it. While working in groups, each member has the responsibility to follow the rules. Investigations can be in the form of questioning

the experts through e-mail, internet browsing, sharing experience and knowledge, and conducting surveys. In its development, project completion steps include observation, experiment, practice, discussion, and field trips (Usmeldi, 2015; Xiaolai & Qinghuai, 2011).

Students can present their findings through images, writing, graphics, symbols, mapping, and others. Prospective teachers can monitor their progress and presentations via chat. They created reports, presentations, web pages, images, and more. As a result of its activities, the progress of the project reported by future teachers was summarized into project progress notes for further development (Usmeldi, 2016; Riantoni, et al., 2017; Saifullah, et al., 2017). Each future teacher received feedback on what he or she made in groups, friends, and colleagues. Online feedback facility was presented to enable individuals to directly comment and contribute to others.

Monitoring and evaluation are assessed through all project processes done by each learner based on their participation and productivity. Project-based learning or assignment is a method of presenting the provided learning materials through a set of tasks that must be done either individually or in groups. The use of project methods also determines the effectiveness and efficiency of learning and provides opportunities for future teachers to conduct their own learning activities and make assignments to their students later.

Based on the project results, there are several principles that can help students become effective independent learners. First, making the tasks meaningful, clear, and challenging, one of the most difficult challenges faced is keeping all group members engaged. While doing an independent activity, it is very easy for students to lose interest and do irrelevant actions, especially if the tasks are routine. Students need to know exactly what they need to do, why they do the job, and what it takes to get the job done. The students remain on task during classwork and complete homework if they address the tasks significantly.

In the monitoring stage, future teachers should emphasis on procedural directives. Instructions must cover the explanation about what to do, why, and how something should be done. Before assigning a task, teachers should consider the essential characteristics of the task and then make time to explain the important characteristics to the students. Establishing the appropriate difficulty level of the tasks assigned to the student is the ongoing engagement required to complete the tasks. If students are expected to

work independently, the task should have a fair difficulty that ensures their success. Students will not be challenged when the tasks are too easy. They will address such tasks as unrelenting jobs. In general, a good task needs to have fair difficulty level so most students see it as a challenging, but doable task. It is important for teachers to monitor students to see if they understand their assignment and the cognitive processes involved (Gani, et al., 2017).

This monitoring also includes checking students' work and returning tasks with feedback. By the time some students are given a class job, the teacher can work with other students. Teachers are encouraged to take 5 or 10 minutes to get around guiding students to see if they understand the task. When students work in groups, then teachers should be in groups in turns and traveling among students working independently. While grading the time-consuming task, teachers should correct students' work and return them with feedback so that students know the shortcomings of their work. Competencies developed in students include discipline-based, interpersonal and intrapersonal competence.

The discipline-based competence focuses on the understanding of the concepts, principles, and theories. Interpersonal competence includes the ability to communicate, collaborate, behave politely, resolve conflict, cooperate, assist others, and establish relationships with other people and society. Intrapersonal competence includes an appreciation of diversity, self-reflection, discipline, high work ethic, healthy self-esteem, emotional control, diligence, independence, and motivation (Dockett & Mestre, 2014; Huang, et al., 2015; Niss, 2017; Baran & Sozibilir, 2017).

Competencies that students gained during the lesson are very important for their success. The nature of project-based learning is collaborative. In groups, the individual strengths and learning styles contribute to the success of the team. The task could motivate, improve problem-solving skills, enhance collaboration, and cultivate resource-management skills.

Many sources describe project-based learning as a method to make students actively involved in solving complex problems. The importance of group working is to develop and practice communication skills. A cooperative group, student evaluation, and online information exchange are the collaborative aspects this method. However, the problems are might be too difficult. That's why teachers should cleverly modify the task so that the difficulty is just at a fair level. Moreover, the implementation of the method

might take longer time, spend money, and need a lot of preparation. To overcome the weaknesses of project-based learning, teachers should continuously check students' progress and remind them to finish the project on time, minimizing and providing simple equipment available in the surrounding environment, and selecting an affordable research location that does not cost much.

### CONCLUSION

The research product was 13 items of props namely harmonic oscillation, auto calorific power measuring instrument, impact props, diffraction grating, simple electric circuit, incline, scale board of magnetic field, refractive index tool, conductive props, business measuring board, Fluid viscosity, BLDC motor, and ad wood aircraft. The results of observations obtained from the project preparation descriptions show the experience of future Physics teacher achieved the highest score on making the schedule and the lowest scores on formulating product benefits, developing feasibility analysis and analyzing environmental impacts. Based on the Physics props trial, it was obtained the highest score on the indicator of analyzing the baseline data, while the lowest score was on the variation test variables. Positive feedback about time-management in completing the project, the ability to identify the topic of the project, the ability to find ideas to support the completion of the project, the ability to test the tools, and the ability to make progress reports on project completion was derived from the interviews. The highest score of students' responses to project completion was on the second data collection indicator and the lowest was the instrument material design indicator.

### REFERENCES

- Adams, W. K., & Wieman, C. E. (2015). Analyzing the many skills involved in solving complex physics problems. *American Journal of Physics*, 83(5), 459-467.
- Balliet, R. N., Riggs, E. M., & Maltese, A. V. (2015). Students' problem solving approaches for developing geologic models in the field. *Journal of Research in Science Teaching*, 52(8), 1109-1131.
- Baran, M., & Sozbilir, M. (2017). An Application of Context-and Problem-Based Learning (C-PBL) into Teaching Thermodynamics. *Research in Science Education*, 1-27.
- Ceberio, M., Almudí, J. M., & Franco, Á. (2016). Design and Application of Interactive Simulations in Problem-Solving in University-Level Physics Education. *Journal of Science Education and Technology*, 25(4), 590-609.
- Cibik, A. S., & Yalçın, N. (2011). The effect of teaching the direct current concept with analogy technique to the attitudes of science education students toward physics. *Procedia-Social and Behavioral Sciences*, 15, 2647-2651.
- Docktor, J. L., & Mestre, J. P. (2014). Synthesis of discipline-based education research in physics. *Physical Review Special Topics-Physics Education Research*, 10(2), 1191-1195.
- Henderson, C. (2016). Renaming Physical Review Special Topics—Physics Education Research. *Physical Review Physics Education Research*, 12(1), 1-13.
- Estrella, E. A., & Valenzuela, A. (2016). Multiple Intelligence and Work Performance of College Teachers. *International Journal of Educational Researchers*, 7(1), 24-32.
- Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (1993). *How to design and evaluate research in education* (Vol. 7). New York: McGraw-Hill.
- Gani, A., Safitri, R., & Mahyana, M. (2017). Improving the Visual-Spatial Intelligence and Results of Learning of Junior High School Students' with Multiple Intelligences-Based Students Worksheet Learning on Lens Materials. *Jurnal Pendidikan IPA Indonesia*, 6(1), 16-22.
- Haji, A. G., & Safitri, R. (2015). The Use of Problem Based Learning to Increase Students' Learning Independent and to Investigate Students' concept Understanding on Rotational Dynamic at Students of SMA Negeri 4 Banda Aceh. *Jurnal Pendidikan IPA Indonesia*, 4(1), 67-72.
- Hande, S., Mohammed, C. A., & Komattil, R. (2015). Acquisition of knowledge, generic skills and attitudes through problem-based learning: Student perspectives in a hybrid curriculum. *Journal of Taibah University Medical Sciences*, 10(1), 21-25.
- Huang, N. T. N., Chiu, L. J., & Hong, J. C. (2016). Relationship Among Students' Problem-Solving Attitude, Perceived Value, Behavioral Attitude, and Intention to Participate in a Science and Technology Contest. *International Journal of Science and Mathematics Education*, 14(8), 1419-1435.
- Khaeroningtyas, N., Permanasari, A., & Hamidah, I. (2016). STEM Learning in Material of Temperature and Its Change to Improve Scientific Literacy of Junior High School. *Jurnal Pendidikan IPA Indonesia*, 5(1), 94-100.
- Nazila, K., & Reza, B. M. (2011). Eliciting Management Education Model of Teaching (MEMT) From a Decade Studies in Iran and Its Use for Teaching. *Procedia-Social and Behavioral Sciences*, 29, 1151-1160.
- Niss, M. (2017). Obstacles Related to Structuring for Mathematization Encountered by Students when Solving Physics Problems. *International Journal of Science and Mathematics Education*, 15(8), 1441-1462.

- Özdamli, F. (2011). The experiences of teacher candidates in developing instructional multimedia materials in project based learning. *Procedia-Social and Behavioral Sciences*, 15, 3810-3820.
- Putra, M. I. S., Widodo, W., & Jatmiko, B. (2016). The Development of Guided Inquiry Science Learning Materials to Improve Science Literacy Skill of Prospective MI Teachers. *Jurnal Pendidikan IPA Indonesia*, 5(1), 83-93.
- Riantoni, C., Yuliaty, L., Mufti, N., & Nehru, N. (2017). Problem Solving Approach in Electrical Energy and Power on Students as Physics Teacher Candidates. *Jurnal Pendidikan IPA Indonesia*, 6(1), 55-62.
- Yerushalmi, E. (2014). Problem solving vs. troubleshooting tasks: The case of sixth-grade students studying simple electric circuits. *International Journal of Science and Mathematics Education*, 12(6), 1341-1366.
- Saifullah, A. M., Sutopo, S., & Wisodo, H. (2017). SHS Students' Difficulty in Solving Impulse and Momentum Problem. *Jurnal Pendidikan IPA Indonesia*, 6(1), 1-10.
- Sumarni, W., Wardani, S., Sudarmin, S., & Gupitasari, D. N. (2016). Project based learning (pbl) to improve psychomotoric skills: a classroom action research. *Jurnal Pendidikan IPA Indonesia*, 5(2), 157-163.
- Supriyanti, F. M. T., & Mulyanti, S. (2015). The Use of Problem Solving Model in The Material of The Genetic Information Flow to Improve The Students' concept Mastery. *Jurnal Pendidikan IPA Indonesia*, 4(1), 73-78.
- Turk, M., Miočić, I., Marinović, M., Turković, I., & Ledić, J. (2015). Croatian Students' Awareness, Understanding and Attitudes Regarding European Dimension in Education. *Procedia-Social and Behavioral Sciences*, 174, 862-869.
- Usmeldi, U. (2015). The Effectiveness of Physics Based Research in Learning Engineering Physics. *Jurnal Pendidikan IPA Indonesia*, 4(1), 79-85.
- Usmeldi, U. (2016). The Development of Research-Based Physics Learning Model with Scientific Approach to Develop Students' scientific Processing Skill. *Jurnal Pendidikan IPA Indonesia*, 5(1), 134-139.
- Liu, X., & Li, Q. (2011). Combination of the Research-based learning method with the Modern Physics Experiment Course Teaching. *International Education Studies*, 4(1), 101-112.
- Yu, K. C., Fan, S. C., & Lin, K. Y. (2015). Enhancing Students' Problem-Solving Skills through Context-Based Learning. *International Journal of Science and Mathematics Education*, 13(6), 1377-1401.



## LEARNING DIFFICULTIES OF THE 5<sup>TH</sup> GRADE ELEMENTARY SCHOOL STUDENTS IN LEARNING HUMAN AND ANIMAL BODY ORGANS

I. Maryani\*<sup>1</sup>, N.N. Husna<sup>2</sup>, M.N. Wangid<sup>3</sup>, A. Mustadi<sup>4</sup>, R. Vahechart<sup>5</sup>

<sup>1,2</sup>Elementary School Education, Ahmad Dahlan University, Indonesia

<sup>3,4</sup>Primary Education, Graduate School, Yogyakarta State University, Indonesia

<sup>5</sup>Education Administration Department, Thaksin University, Thailand

DOI: 10.15294/jpii.v7i1.11269

Accepted: November 27<sup>th</sup>, 2017. Approved: February 21<sup>st</sup>, 2018. Published: March 19<sup>th</sup>, 2018

### ABSTRACT

Natural Science is an elementary school subject that requires students to organize ideas and concepts about the natural world gained from experiences through a series of scientific processes such as investigating, composing, and presenting ideas. The high complexity causes many cases of learning difficulties. This study aims to diagnose the learning difficulties that occur on 5th-grade elementary school students. The research was conducted in Muhammadiyah Pakem Elementary School, Sleman, Yogyakarta Special Regency. The subjects were 29 of 5th-grade elementary students. Data collection techniques were interviews, tests, and documentation. Data analysis techniques were descriptive statistic as a quantitative analysis and interactive model as a qualitative analysis. The learning difficulties were diagnosed by describing the students who were identified having learning difficulties; localizing the difficulties; and determining the factors that cause learning difficulties. The results showed that the difficulties experienced by students were in basic competence 1.1-1.5 (human blood circulation organs). The average percentage of students' learning difficulties in Basic Competence 1.1 was 48%; Basic Competence 1.2 was 51.1%; Basic Competence 1.3 was 57.6%; Basic Competence 1.4 is 64.7%; and Basic Competence 1.5 is 53.7%. The highest percentage of learning difficulties was in Basic Competence 1.4 (identifying human circulatory organs). It was caused by the students' low attention and motivation to learn natural science, the imprecise teaching methods, the parents' attention, and the negative influence of mass media.

© 2018 Science Education Study Program FMIPA UNNES Semarang

**Keywords:** natural science, blood circulation system.

### INTRODUCTION

Learning difficulties can hamper students in reaching the maximum achievement. It is one of the psychological disorders including hearing loss, thinking, speaking, reading, writing, spelling, or performing mathematical calculations (Cortiella & Horowitz, 2014). In Indonesia, learning difficulties allegedly become the main reason for students' low achievement. PISA 2012 measured the understanding of 15-year-old students in the field of mathematics, reading, and science, which

then ranked Indonesia to the low position of 65 participating countries. Indonesia was ranked to the 64th position on mathematics (score: 375), the 61st position on reading (score: 396), and the 64th position on science (score: 382).

NAEP (National Assessment of Educational Progress) (2013) stated that on reading and mathematics literacy in the United States, there is 69% of the 4th grade students and 60% of the 8th grade students who have trouble on reading. Learning difficulties of Mathematics on the 4th grade students is 45% and 65% on the 8th grade students. These data suggest that learning difficulties on the 4th to 8th grade students show relatively high numbers (Cortiella & Horowitz, 2014). Students' learning difficulties affect the learning

\*Correspondence Address  
E-mail: [ika\\_mail87@ymail.com](mailto:ika_mail87@ymail.com)

process (Cavendish, 2013). Especially for elementary school students, learning success at this level will be the determinant of a successful learning in the next level (high school).

At the elementary school level, learning difficulty problems often arise in both mathematical and rote subjects. One of such subjects is natural science, since it bears a characteristic which is definitely scientific. Natural science is a branch of knowledge that is originated from natural phenomena. Natural Science is defined as a collection of knowledge about the objects and natural phenomena which are gained from scientists' thought and investigation through experiments using scientific methods.

Experiments have been conducted to achieve the goals of science learning, including the enrichment of students' perception over the concepts in science and its products; scientific-practical competencies and problem solving skills; scientific 'habits of mind'; understanding of how science and scientists work; awareness and motivation (Duschl, 2008; Hofstein & Mamlok-Naaman, 2007). Teaching natural science in elementary schools should use fun methods and concrete media or media that are related to the students' daily life. Learning characteristic of elementary school students is that they learn through concrete things (Riggs & Enochs, 1990). Children can already be given the basic sciences such as reading, writing, and arithmetic. Elementary school children can also be given the basic knowledge related to human life, animal, natural environment, socio-cultural environment, and religion.

The characteristic of natural science learning in elementary school is emphasizing on the process of finding out, on the initial knowledge which later determines the knowledge construction that will be built. Therefore, teaching natural science to elementary school students needs high tenacity and patience. Natural science is a very important lesson for students (Chiappetta & Koballa Jr, 2014). It is important because natural science is necessary for everyday life. However, students find difficulties in learning natural science. Learning difficulties in studying natural science in elementary school usually happen to the students of upper-level grade, especially the 5th grade students. Natural science lesson in the grade 5 elementary school already needs high logic of thinking since the material of it is difficult and discussing on the real phenomena that students cannot see and feel directly.

The difficulties in learning natural science in the 5th grade students also happen in Muham-

madiyah Pakem Elementary School, Yogyakarta, Indonesia. Those difficulties were indicated from the results of teacher interviews conducted by the researchers. The findings showed that the 5th grade students got difficulties in understanding the natural science subjects taught by teachers, especially on the material of human and animal organs. The results of learning natural science material which is focused only on the subject of human and animals' organs in the 5th grade students of Muhammadiyah Pakem elementary school, Sleman, Yogyakarta regency were measured by using several tests as the instrument. The researchers also explain the factors that cause learning difficulties in natural science learning. In this research, we used purposive sampling method involving 29 respondents of 5th grade students of Muhammadiyah Pakem Elementary School and a teacher. Data analysis techniques used were descriptive statistics for quantitative data and interactive models from Miles and Huberman for qualitative data.

## METHODS

This research used mix-method with embedded konkrue strategy, which is strategy of mixed method that apply one stage of collecting quantitative and qualitative data at one time. Researchers want to prove the difficulties of learning natural science which is limited on the subject of human and animals organs in 5th grade students in Muhammadiyah Pakem elementary school using test instrument. Researchers also studied the factors causing difficulties in natural science learning. In this research, the researchers employed purposive sampling method with 30 respondents of 5th grade students from Muhammadiyah Pakem elementary school and 1 teacher. The data analysis techniques applied were descriptive statistics for quantitative data, and interactive models from Miles and Huberman for qualitative data.

## RESULTS AND DISCUSSION

### Identification of the students who have difficulties in learning natural science

Based on the test results that have been finished by 29 respondents of 5th grade students of Muhammadiyah Pakem Elementary School, the results obtained can be seen in figure 1. The value is obtained by using the parameter of a scale 0-100 and the passing grade is 80 in accordance with the minimum criteria of learning mastery in the school.

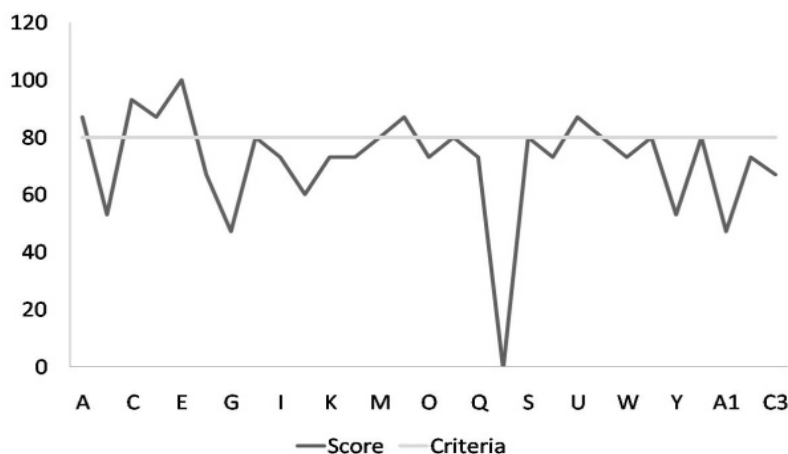


Figure 1. Criteria for Student Achievement.

Figure 1 shows that 55.1% of 5th grade students have learning difficulties for which it is later categorized as an incomplete criteria of learning outcomes. The percentage of the students who experience learning difficulties illustrates that most of the students in the 5th grade have difficulties in studying the subject of human and animal organs.

The difficulties of learning can also be seen from the analysis of the test results completed by students. The test questions used in the experiment have been mapped through the indicators, so it can be recognized which indicators

are perceived difficult by students and may cause difficulties in learning natural science, especially on the subject of human and animal organs.

**The assessment results of the subject on human and animal organs**

Based on the assessment results that have been completed by the 5th grade elementary students of Muhammadiyah Pakem Elementary School, with 29 students as the respondents, researchers classify the question into low, moderate, and high level of difficulty. The results of the assessment can be seen in table 1.

Table 1. Level Difficulties of Question

Question Number	Percentage of True answer	Percentage of False answer	Difficulty Level
1	51.1%	48.9%	Moderate
2	62.2%	37.8%	Moderate
3	48.9%	51.1%	Moderate
4	48.9%	51.1%	Moderate
5	48.9%	51.1%	Moderate
6	62.2%	37.8%	Moderate
7	41.8%	58.2%	Moderate
8	48.9%	51.1%	Moderate
9	41.8%	58.2%	Moderate
10	44.9%	55.1%	Moderate
11	62.2%	37.8%	Moderate
12	27.6%	72.4%	High
13	41.8%	58.2%	Moderate
14	34.7%	65.3%	Moderate
15	37.8%	62.2%	Moderate



16	37.8%	62.2%	Moderate
17	41.8%	58.2%	Moderate
18	37.8%	62.2%	Moderate
19	24.5%	75.5%	<b>High</b>
20	44.9%	55.1%	Moderate
21	34.7%	65.3%	Moderate
22	48.9%	51.1%	Moderate
23	58.2%	41.8%	Moderate
24	65.3%	34.7%	Moderate
25	41.8%	58.2%	Moderate

From table 1, it can be seen that some 5th grade students of Muhammadiyah Pakem Elementary School have difficulties on the certain basic competencies while studying natural science, especially on the subject of human and animal organs. It can be seen from the percentage of the students' failure in answering the test questions that have been mapped according to the basic competencies and learning indicators. From the percentage of Table 1, it can also be seen that students that have learning difficulties in the easy category were 0%, in the moderate category were 92%, and in the high category were 8%.

### The Difficulties in Learning Natural Science

From the analysis of the students' failure in answering the test questions, it seems that most students have learning difficulties on the certain basic competencies.

#### a. *The difficulties in learning basic competency 1.1: Identifying the function of the human respiratory organs*

The learning difficulties on the indicator 1.1 include the number of the students' failures in answering the questions related to the mechanisms of the human respiratory system, and the completeness of the human respirators which are presented in table 2.

**Table 2.** The Learning Difficulties of Basic Competency 1.1

Question Item	Percentage of True answer	Percentage of False answer
1. The branch of the throat is called....	51.1%	48.9%
2. When we take a breath, air will enter through the nose, then go to....	62.2%	37.8%
3. When the air exchanges in the respiratory process, there occurs....	48.9%	51.1%
4. The inspiration for human respiration occurs because the diaphragm....	48.9%	51.1%
5. Completeness of the respiratory system in humans are....	48.9%	51.1%
Average	52%	48%

From table 2, it can be inferred that 48% of 5th grade students have difficulty in studying basic competency 1.1 for that requires them to identify the respiratory organs in human body. Based on the analysis of the question items, students' learning difficulties on the basic competency 1.1 are caused by the following factors: (1) The answer choices of the test had a good deceiver power so that the students' good comprehension towards the material was required here; (2) The teacher needs to use media in explaining concepts to avoid multiple interpretations and misconceptions, so that the students can truly comprehend the learning material rather than simply memorize it; (3) The students'

comprehension towards the abstract concept was so low that it took teachers' skill in using appropriate media and methods based on the characteristics of the learning material.

*b. The difficulties in learning basic competency 1.2: Identifying the functions of the respiratory organs*

The assessment aspect of the learning difficulties on "identifying the function of the respiratory organs" is the students' failure in answering the questions related to the respiratory mechanism in animals and the functions of animals respiratory organs is presented table 3.

**Table 3.** The Learning Difficulties of Basic Competency 1.2

Question Item	Percentage of True answer	Percentage of False answer
6. The bird breathing apparatus at flight is called...	62.2%	37.8%
7. Gas exchange on the respiration process of a fish is located on...	41.8%	58.2%
8. On the fish respiration, water enters the mouth when....	48.9%	51.1%
9. In the bird's respiratory system, there are two airsacs. When the bird breathes, the air will flow through the....	41.8%	58.2%
Average	48.5%	51.5%

From table 3, it can be concluded that 51.5% of 5th grade students have difficulties in studying basic competency 1.2 which requires them to identify the function of respiratory organs. Based on the item analysis, students' learning difficulties on the basic competency 1.2 are caused by the following factors: (1) The students' comprehension over the function of the respiratory organs was still low. This is due to the lack of students' participation in learning; (2) The answer choices of test had a good deceiver power so that the students' good comprehension towards the learning material was required; (3) The teacher needs to use media in explaining concepts to avoid multiple interpretations and misconceptions so that students can truly comprehend the learning material rather than simply

memorize it; (4) The students' comprehension towards the abstract concept was so low that it took teachers' skill in using appropriate media and methods based on the characteristics of the learning material.

*c. Difficulties in learning basic competencies 1.3: Identifying the function of human digestive organs and the relation to food and health*

The assessment aspect of learning difficulties on "identifying the function of human digestive organs" includes the students' failure in answering the questions related to human digestive mechanisms, the functions of digestive organs in the human body, the obstruction in the digestive system, and the nutritional content in food.

**Table 4.** The Learning Difficulties of Basic Competency 1.3

Question Item	Percentage of True answer	Percentage of False answer
10. A deficiency of vitamin B6 can cause....	44.9%	55.1%
11. Appendicitis is inflammation of the appendix which is caused by....	62.2%	37.8%
12. The sprouts of mung bean contain high nutrition if it is eaten by...	27.6%	72.4%
13. The combination of foods containing balanced nutrition consists of....	41.8%	58.2%
14. Food from the stomach will be absorbed and channeled to all parts of the body. The absorption of food is occurred in...	34.7%	65.3%
Average	42.4%	57.6%

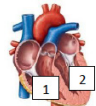
From table 4, it can be inferred that 57.6% of 5th grade students have difficulties in studying basic competency 1.3 which requires them to identify the function of human digestive organs and its relation to food and health. Based on the item analysis, students' learning difficulties on basic competency 1.3 are caused by the following factors: (1) The uninteresting method of the teacher in delivering the lesson materials, or the lack of media usage which later led to the students' feeling of bore and unmotivated to learn natural science; (2) The answer choices of the test had a good deceiver power so that the students' good comprehension towards the learning material was required; (3) The inadequate comprehension of the previous material caused disruption

on the process of understanding the next material; (4) The teacher needs to use media in explaining concepts, especially an abstract concept. It is necessary to avoid the multiple interpretations and misconceptions, so that students can truly comprehend the material rather than simply memorize it.

*d. Difficulties in learning basic competency 1.4: Identifying human blood circulatory organs*

Assessment aspect of learning difficulties on "identifying human blood circulatory organs" is the students' failure in answering the questions related to the mechanisms of human blood vessel system and the function of human blood vessels.

**Table 5.** The Learning Difficulties of Basic Competency 1.4

Question Item	Percentage of True answer	Percentage of False answer
15. Blood vessels that stream the blood outside the heart are called...	37.8%	62.2%
16. The blood vessels that stream the blood from the heart to the entire body are called....	37.8%	62.2%
 17. When the heart part 1 and 2 are contracting, what happens is....	41.8%	58.2%
18. One function of capillary vessels is....	37.8%	62.2%
19. The blood vessels that are in charge of carrying oxygenated blood from the lungs to the left atrium of the heart is called....	24.5%	75.5%
Average	35,4%	64,6%

From table 5, it can be seen that 64.6% of 5th grade students have difficulties in studying basic competency 1.4 which is related to the identification of the human blood circulatory organs. Based on the items analysis, students' learning difficulties on basic competency 1.4 are due to these following factors: (1) The answer choices of the test had a good deceiver power so that require the students' good comprehension over the learning material; (2) In delivering the lesson material, the teacher needed to use media so that the students would not get bored and got their motivation back to learn natural science; (3) Inadequate comprehension of the previous material caused disruption on the process of understanding the next material; (4) The teacher needs to use media or visual properties in explaining

concepts, especially an abstract concept. This is necessary to avoid multiple interpretations and misconceptions of the students, so that they can truly comprehend the learning material; (5) The students' motivation was still low which then affects the process of absorbing the learning material.

*e. Difficulties in learning basic competency 1.5: Identifying the disorders of human blood circulatory organs*

The assessment aspect of learning difficulties on "identifying the disorders of human blood circulatory organs" includes the students' failure in answering the diseases which are caused by abnormalities in the human circulatory system.

**Table 6.** The Learning Difficulties of Basic Competency 1.5

Question Item	Percentage of True answer	Percentage of False answer
20. The disease of the circulatory system that is associated with blood pressure is...	44.9%	55.1%
21. The disease of the circulatory system that increases the number of leukocytes cells uncontrollably then eating erythrocyte cells and blood preservation is....	34.7%	65.3%
22. The best way to maintain the health of blood circulation system is....	48.9%	51.1%
23. The fat that attaches to the walls of blood vessels can cause ...	58.2%	41.8%
24. The veins on Mr. Herlambang's right calf are prominent. It is very different from the left one. It is possible that Mr. Herlambang may have....	65.3%	34.7%
25. Stroke can occur due to...	41.8%	58.2%
Average	48.7%	51.3%

From table 6, it can be inferred that 51.3% of the 5th grade students have difficulties in studying basic competency 1.5 which requires them to identify the disorders of human blood circulatory organs. Based on the item analysis, the students' learning difficulties on basic competency 1.5 are caused by of these following factors: (1) The answer choices of the test had a good deceiver power so that the students' good comprehension of the learning material was required here; (2) The uninteresting method applied by the teacher in delivering the lesson material, or the lack of media usage in learning natural science led to the students' boredom which then affects their motivation to learn natural science; (3) The teacher needs to use media or visual properties

in explaining concepts, especially an abstract concept. This is necessary to avoid multiple interpretations and misconceptions of the students, so that the students can truly comprehend the learning material.

Based on the research data, it is found that 55.1% of elementary school students of Muhammadiyah Pakem have difficulties in studying natural science on human and animal organs subject. Learning difficulties is the difficulties experienced by students so that they cannot achieve a certain level of learning qualifications (Hale, J., et al, 2010; McLeskey & Waldron., 2011; Cavendish, 2013). The results of the test analysis show that the students have difficulties in solving the problems of certain basic competencies. Moreo-

ver, the level of learning difficulties experienced by students in each basic competency is different one and another.

The results obtained in this research are later analyzed thoroughly and showing up that the students have difficulty on the basic competencies; which are 48% in basic competency 1.1, 51.5% in basic competency 1.2, 57.6% in basic competency 1.3, 64.6% in basic competency 1.4, and 53.7% in basic competency 1.5.

The most significant difficulty experienced by the students is in the basic competency 1.4 which requires them to identify the human blood circulatory organs. It can be seen from the percentage of difficulty gained in this basic competency which reached the highest percentage. The learning difficulties of the basic competency 1.4 lie on the lack of the students' ability to comprehend the indicators in identifying the functions of the human blood circulatory organs, explaining the human blood circulatory process, analyzing the works of human blood circulatory organs.

Learning difficulties experienced by students can also be seen from the percentage level of the students' failure in answering the questions. The students' errors in answering the questions can be interpreted that the deceiver power of the answer choices is effective. Students can easily distracted by the answer choices if they do not master the concepts of learning materials, especially the abstract concepts. The students were still unable to distinguish between bronchus (throat branch) and bronchioles (bronchus branch), throat (digestion organ) and esophagus (respiratory organ). The students assumed that those organs are the same, but actually they have different functions even though located in the same place.

Referring to some relevant studies conducted by (Geary, 2013; Kaldenberg, et al, 2015; Schoenfeld, 2016), the research results showed that the students usually have learning difficulties due to the lack of learning material concept mastery. Learning material concept is the base or foundation of science learned by students which means, when students do not understand the concept, there will be misconceptions that later impact on learning difficulties experienced by students (Cakir, 2008). Lack of the learning material concept mastery can be caused by several factors.

Moreover, according to (Cooper, S. A. et al., 2009) "Factors that can emerge learning difficulties can be classified into two groups namely internal factors (physical, psychological, fatigue) and external factors (family, school, community)". Having been revealed, there are several

factors that cause students experience learning difficulties in accordance with the results of interviews and documentation conducted on the students and a teacher. The internal factors include both the students' low attention and low motivation to learn natural science. Meanwhile, the external factors are the teachers' teaching methods, parental attention, and mass media.

The students' low comprehension in learning material concepts is caused by internal factors such as student' lack of attention and boredom which then lead to their low participation in the lesson. Furthermore, they even prefer to chat and play with their classmates during the learning process. The students' low motivation in the learning process can be indicated from the students' inactiveness while studying natural science and the students' low spirit in learning natural science. Those indicators are reflected on the students' study time at home, especially on the natural science subject which is still low.

The students' low attention, low learning motivation and low comprehension of the learning material concept which then emerge misconceptions may occur due to the teacher's uninteresting methods of teaching. Based on the interviews on the students and a teacher, teaching method is one of the factors that lead to the students' difficulties in learning natural science. The teacher's teaching method used previously was only lecturing without using media that can support the explanation of the learning materials. The teacher only used the textbook, yet the facilities provided by the school are complete.

In teaching human and animals' organs materials, teachers cannot use only textbooks to teach. It is because the students need to have a visualization of the human body organs, human blood circulatory system, human respiratory system, and human digestive system which are processing inside the human body, so that the students cannot see the processes directly. The characteristics of children at elementary school level who are in the phase of concrete operation think based on the concrete or real experience. They are not able yet to think abstractly, such as imagining how the process of blood circulation occurs (Fedewa, et al., 2017).

If the teacher is already aware of the students' thinking development, he or she can choose the appropriate teaching methods for the students, so that the learning difficulties can be minimized. The teacher can apply various learning methods in teaching if only he or she already masters the pedagogic and professional capa-

bility. It will later trigger the development of the students' comprehension towards the learning materials. The teacher must understand the basic concepts of the learning material so that the mistakes in teaching the materials will be minimized along with the learning difficulties experienced by the students in comprehending the concepts.

The teacher's performance, the experience of teaching pupils with special needs, the behavior of disable people, and the teachers' role which influence the creation of the rapports between teacher and students in learning the lessons was identified. The effects of teachers' training and development for pupil's success and pupil self-perception have been identified as well (Brady & Woolfson, 2008). In addition, students become more interested in learning so that their motivation will be getting higher (Maryani & Martaningsih, 2015).

Parents of the students with special needs have extra barriers to the parental attention than parents of the common students. Their attention is also a contributing factor in creating learning difficulties experienced by some students (Fishman & Nickerson, 2015). It can be detected from the interview results with some students whose parents are entrepreneurs who usually work out of the town. The students' time to meet their parents is also very limited. Because their parents are busy with their own work, their children's learning achievements are then relied on the schools and tutoring institutions only.

Mass media and internet usage are also the factors that cause learning difficulties experienced by students (Chu, 2014; Takahashi & Tandoc, 2016). This can be indicated from the students' activities. They prefer to play games, use mobile phones, and watch television rather than doing activities that support their learning process such as having an additional course or studying together with friends. Based on the interview results on the students, interaction with friends does not belong to the factors that cause the difficulties in learning natural science experienced by students.

## CONCLUSION

The learning difficulties experienced by the 5<sup>th</sup> grade students of the elementary school on the human and animal organs subject are based on the following basic competencies: 1.1 on identifying the functions of human respiratory organs include the number of students' failure in answering the questions related to the mechanisms of

the human respiratory system, and the completeness of the human respirator (48%), 1.2 on identifying the functions of the respiratory organs (51.1%), 1.3 on identifying the functions of human digestive organs and their relation to food and health (57.6%), 1.4 on identifying the human blood circulatory organs (64.7%), and 1.5 on identifying the disturbances in human circulatory organs (53.7%).

The discussion results of qualitative data indicated that the factors causing difficulties in learning natural science experienced by the 5<sup>th</sup> grade students of elementary school are the students' low attention to the natural science lesson, the low motivation to learn natural science, the teacher teaching methods, the parents' attention, and mass media.

## ACKNOWLEDGMENTS

Thanks to Ministry of Research, Technology, and Higher Education of Republik Indonesia for the grant under Inter-collegiate Joint Research Scheme with grant number: PEKERTI-059/SP3/LPP-UAD/IV/2017 dated April 17, 2017, and Institute of Research and Development of Ahmad Dahlan University for supporting this research.

## REFERENCES

- Brady, K., & Woolfson, L. (2008). What teacher factors influence their attributions for children's difficulties in learning?. *British Journal of Educational Psychology*, 78(4), 527-544.
- Cakir, M. (2008). Constructivist approaches to learning in science and their implications for science pedagogy: A literature review. *International journal of environmental & science education*, 3(4), 193-206.
- Cavendish, W. (2013). Identification of learning disabilities: Implications of proposed DSM-5 criteria for school-based assessment. *Journal of Learning Disabilities*, 46(1), 52-57.
- Chiappetta, E. L., & Koballa Jr, T. R. (2014). *Science instruction in the middle and secondary schools* (8th ed.). College of Education Faculty Publications: Pearson.
- Chu, H. C. (2014). Potential Negative Effects of Mobile Learning on Students' Learning Achievement and Cognitive Load--A Format Assessment Perspective. *Journal of Educational Technology & Society*, 17(1), 12-18.
- Cooper, S. A., Smiley, E., Jackson, A., Finlayson, J., Allan, L., Mantry, D., & Morrison, J. (2009). Adults with intellectual disabilities: prevalence, incidence, and remission of aggressive behavior

- and related factors. *Journal of Intellectual Disability Research*, 53(3), 217-232.
- Cortiella, C., & Horowitz, S. H. (2014). The state of learning disabilities: Facts, trends and emerging issues. *New York: National Center for Learning Disabilities*, 2-45.
- Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of research in education*, 32(1), 268-291.
- Fedewa, A. L., Toland, M. D., Usher, E. L., & Li, C. R. (2016). Elementary School Students' Health-Related Self-Beliefs. *International Electronic Journal of Elementary Education*, 9(1), 151-166.
- Fishman, C. E., & Nickerson, A. B. (2015). Motivations for involvement: A preliminary investigation of parents of students with disabilities. *Journal of Child and Family Studies*, 24(2), 523-535.
- Geary, D. C. (2013). Early foundations for mathematics learning and their relations to learning disabilities. *Current directions in psychological science*, 22(1), 23-27.
- Hale, J., Alfonso, V., Berninger, V., Bracken, B., Christo, C., Clark, E., & Dumont, R. (2010). Critical issues in response-to-intervention, comprehensive evaluation, and specific learning disabilities identification and intervention: An expert white paper consensus. *Learning Disability Quarterly*, 33(3), 223-236.
- Higgins, K., Crawford, L., & Silvestri, S. (2016). Student Perceptions of an Online Mathematics Curriculum Designed for Students with Learning Difficulties. *Social Welfare: Interdisciplinary Approach*, 2(6), 108-123.
- Hofstein, A., & Mamlok-Naaman, R. (2007). The laboratory in science education: the state of the art. *Chemistry education research and practice*, 8(2), 105-107.
- Kaldenberg, E. R., Watt, S. J., & Therrien, W. J. (2015). Reading instruction in science for students with learning disabilities: A meta-analysis. *Learning Disability Quarterly*, 38(3), 160-173.
- Karpudewan, M., et al. (2017). *Introduction: Misconceptions in Science Education: An Overview. In Overcoming Students' Misconceptions in Science (pp. 1-5). Springer Singapore. Singapore: Springer.*
- Kendeou, P., Broek, P., Helder, A., & Karlsson, J. (2014). A cognitive view of reading comprehension: Implications for reading difficulties. *Learning disabilities research & practice*, 29(1), 10-16.
- Loeb, S., Soland, J., & Fox, L. (2014). Is a good teacher a good teacher for all? Comparing value-added of teachers with their English learners and non-English learners. *Educational Evaluation and Policy Analysis*, 36(4), 457-475.
- Maryani, I., & Martaningsih, S. T. (2015). Correlation between Teacher's PCK (Pedagogical Content Knowledge) and Student's Motivation in Primary School. *International Journal of Evaluation and Research in Education*, 4(1), 38-44.
- McLeskey, J., & Waldron, N. L. (2011). Educational programs for elementary students with learning disabilities: Can they be both effective and inclusive?. *Learning Disabilities Research & Practice*, 26(1), 48-57.
- OECD. (2012). *PISA 2012 Results in Focus (What 15-year-olds know and what they can do with what they know)*. Programme for International Student Assessment.
- Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education*, 74(6), 625-637.
- Schoenfeld, A. (2009). Learning to think mathematically: Problem-solving, metacognition, and sense-making in mathematics. *Colección Digital Eudoxus*, (7), 19-27
- Takahashi, B., & Tandoc Jr, E. C. (2016). Media sources, credibility, and perceptions of science: Learning about how people learn about science. *Public Understanding of Science*, 25(6), 674-690.
- Wendt, J. L., & Rockinson-Szapkiw, A. (2014). The effect of online collaboration on middle school student science misconceptions as an aspect of science literacy. *Journal of Research in Science Teaching*, 51(9), 1103-1118.



### STUDENTS' ERRORS IN SOLVING SCIENCE REASONING-DOMAIN OF TRENDS IN INTERNATIONAL MATHEMATICS AND SCIENCE STUDY (TIMSS)

A. P. Utomo\*<sup>1</sup>, E. Narulita<sup>2</sup>, K. Yuana<sup>3</sup>,  
K. Fikri<sup>4</sup>, B. Wahono<sup>5</sup>

<sup>1,2,3,4</sup>University of Jember, Jember, Indonesia

<sup>5</sup>National Taiwan Normal University, Taipei, Taiwan

DOI: 10.15294/jpii.v7i1.11352

Accepted: October 10<sup>th</sup>, 2017. Approved: February 19<sup>th</sup>, 2018. Published: March 19<sup>th</sup>, 2018

#### ABSTRACT

This research aims to identify the errors of students' answers in solving the TIMSS cognitive domain of reasoning. This research was a qualitative descriptive research. A total 259 students from four secondary schools located in rural and urban areas in Jember, East Java participated in a paper and pencil test. Error identification was examined by reducing the result of wrong students' answer and grouping based on error type of general errors. The results showed that the average percentage of total errors from the four schools were contradicting error of 7.3%, disregarding evidence error of 5.2%, misreading error of 45.7%, and opinion-based judgment error of 40.9%. In conclusion, there were four types of general errors made by students in answering TIMSS test item of reasoning domain with misreading and disregarding evidence as the highest and lowest error, respectively.

© 2018 Science Education Study Program FMIPA UNNES Semarang

**Keywords:** students' errors, TIMSS, cognitive domain of reasoning.

#### INTRODUCTION

The quality of education is often used as a barometer of a country's development. Students' ability to solve math, science, reading and their application in daily life is seen as a good quality illustration of special education for students (Johar, 2012). Indonesia had five times participated in the Trends in International Mathematics and Science Study (TIMSS), an achievement program that measures students' achievement levels in both content and cognitive domains (Akilli, 2015; Angraini & Wasis, 2014).

Based on the results of TIMSS for last four years, Indonesia lied in the rank of the top five average from below (Akilli, 2015). In its participation, Indonesia only reached Low Internatio-

nal Benchmark. The result of TIMSS 2011 in the field of science showed that the high order thinking skills of Indonesian students remain in the low category which is under the international average score. At these levels, Indonesian students were generally judged only to be able to remember scientific facts, terms, laws and to use them in drawing simple conclusions (Angraini & Wasis, 2014). The average percentage of correct answer of cognitive domains of Indonesian students was low. The correct answers of knowing, applying and reasoning domain of Indonesian students were only 36%, 27%, and 20%, respectively (Angraini & Wasis, 2014; Mullis et al., 2012).

Those result shows that reasoning domain was the lowest level for the Indonesian students. It indicates that the capability for analyzing, synthesizing, and generalizing data and concepts of science into the new milieu in their daily life was weak. Those results also denote that the errors

\*Correspondence Address:  
E-mail: erlia.fkip@unej.ac.id



made by students are terribly high. It might happen due to some conditions, first, teachers mostly train students using C1 and C2 level of cognitive domain (Marlina et al., 2017), and second, the lack of ability of Indonesian students to think critically (Busyairi & Sinaga, 2015). Critical thinking becomes a fundamental skill to overcome not only any problems offered in the test of TIMSS but also the problems in daily life (Gierl, 2007). Students' error is defined as an inappropriate response in answering tasks (Markawi, 2015). Detailed error analysis is needed in order to identify the student errors, possible causative factors and provide the ways addressing the problem as well. Through the error analysis, the weaknesses of

students in solving the problems will be obtained clearly. Errors made by students can be used as a consideration to improve teaching and learning activities. Furthermore, it can enhance students' learning outcome

Analysis of students' error is considered as the main source to diagnose difficulties of learning and to access students' reasoning (Batanero et al., 1994; Lim, 2010; Brodie, 2014). Prevost and Lemons (2011) found that the types of errors made by students in the theoretical framework of problem-solving for biological concepts are divided into two types namely general errors and specific errors (table 1) (Prevost & Lemons, 2016).

**Table 1.** Students' Errors of Solving Biology Problems

<b>Problem Solving Errors</b>	<b>Description</b>
<i>Domain-general errors</i>	
<i>Contradicting</i>	Stated two ideas that were in opposition to each other
<i>Disregarding Evidence</i>	Did not use some or all of the data provided in the problem
<i>Misreading</i>	Read the question prompt or answer options incorrectly
<i>Opinion-Based Judgment</i>	Gave an opinion and did not use biology content knowledge
<i>Domain Specific errors</i>	
<i>Making Incorrect Assumptions</i>	Stated that the graph or other visual representation provides no useful information
<i>Misunderstanding Content</i>	Showed incorrect understanding of content knowledge.

This study aimed at identifying and clarifying Indonesian students' errors when solving reasoning tasks. Students having intuition while experiencing or solving problems may support science teachers to improve their achievement.

## METHODS

The research was conducted in four secondary schools located in a rural and urban area of Jember, the Province of East Java. A total of 259 students from those schools participated in both paper and pencil test. Questionnaire and interview to the science teacher were also used to collect data as the purpose was to provide additional information for analyzing the students' answer. Tenth-reasoning science test items of TIMSS were used as test questions. The objective questions of TIMSS were modified into essay questions

by adding the reason for each students' answer.

After the test, the results of the sample were examined to be compared with those Indonesian students participated in the TIMSS surveys. For this purpose, the percentages of correct answers of Indonesian students participated in the TIMSS 2011 survey with those of students in this study for tenth TIMSS tasks were compared. The tasks that were difficult for Indonesian students in the TIMSS 2011 survey were also difficult for the students in this study. After all students' answers were collected, data reduction was determined by examining the student's work and selecting the wrong answer and then grouping the errors based on the general error domains, namely: (1) contradicting; (2) disregarding evidence; (3) misreading; and (4) opinion-based judgment (Prevost & Lemons, 2016). The analyzing and grouping errors' answer used qualitative content analysis (Patton,

1990) and matches the keywords of each general error domain and students' answer. The percentage of each type of error can be determined by using the following formula.

$$P = \frac{n}{N} \times 100\%$$

Note:

P : Percentage of each error

N : Number of errors for each error

N : Number of errors for all error

The criteria of problem-solving ability based on TIMSS cognitive domain used the criteria as in table 2 (Arikunto, 2009).

**Table 2.** Percentage Criteria of Problem Solving Capability of Criteria Value

Value	Criteria
$0\% \leq P < 20\%$	Very low
$20\% \leq P < 40\%$	Low
$40\% \leq P < 60\%$	Normal
$60\% \leq P < 80\%$	High
$80\% \leq P < 100\%$	Very high

## RESULTS AND DISCUSSION

The results were qualitative data from students' wrong answers which were analyzed and interpreted according to the predetermined criteria.

**Table 3.** Percentage of Student Error in Answering TIMSS Reasoning Domains

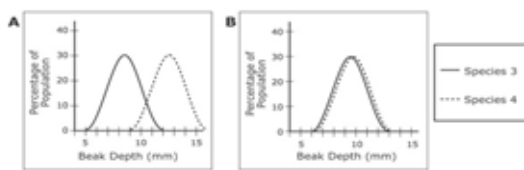
School / Class	Error			
	Ct	DE	Mr	OBJ
School 1				
A	17.3%	5%	35.2%	42.5%
B	5.1%	1.3%	40.5%	53.1
Average	11.2%	3.1%	37.8%	47.8%
School 2				
A	13.6%	13.6%	43.8%	29%
B	8.4%	9.9%	38.4%	43.3%
Average	11%	11.7%	39.6%	36.1%
School 3				
A	1.2%	10.3%	49%	39.5%
B	1.4%	1.7%	35.2%	58.2%
Average	1.3%	6%	42.1%	48.8%
School 4				
A	10.2%	0%	46.5%	43.3%
B	1%	0%	80.6%	18.4%
Average	5.6%	0%	63.5%	30.8%
Average total	7.3%	5.2%	45.7%	40.9%

\*Ct=contradicting; DE=disregarding evidence; Mr=misreading. OBJ=opinion based judgement.

Overall, the most common error was misreading of 45.7%, followed by opinion based judgment, while disregarding evidence was the least errors (table 2). The details of each error made by students are explained below.

### Misreading Error

The most frequent errors that the students did were misreading (table 3). For instance, students were asked to answer the following question: *“Two other species (species 3 and 4 species) live on the Santa Maria Island, which also has a range of seed types. Which of the following graphs shows a range of break depths for species 3 and species 4 that would best ensure the survival of both species on the Santa Maria island?”*



*Explain why this range of the beak depths is best.”*

Student's answer was "A. because the above chart shows the number of bird populations". The Answer is the correct choice but the reason was false. The question requires the students to compare which graph is better to survive, while the students' answers have no relation to the question. It just repeated the information on the problem. It was possible because the students read in a hurry so they did not completely understand the main key to the question. This error belongs to misreading that was caused by quick answering the question while reading it. Students tended to be less thorough in reading resulting in choosing the wrong answers. In addition, students tended to ignore the problem and may choose not to answer it. The errors that were often done by the students in solving the problem are translation errors, i.e. errors in changing information. Students are having difficulty in digesting or understanding the language, and interpreting words or symbols (Arslan et al., 2012).

Many students ignored some questions so that some questions were left without answers. According to the results of the interviews with teachers, students' motivation was low and students tended to get bored with memorizing materials. Moreover, students did not pay attention to questions and they answered many questions without reading and understanding the materials first. Students tend to be less prepared and cheat on daily tests.

### Opinion-based Judgment Error

Opinion-based judgment errors are errors that express opinions without applying biological knowledge content. Students have an opinion in answering questions based on their feelings that the answers seem to be true. This relates to the limitations of factual knowledge with marked misconceptions errors. A misconception is a part of the wrong concept framework but it is considered as correct by the students so that there are consistent and repeated errors (Natalia&Subanji, 2016). It is needed to understand the basic concepts that will facilitate subsequent concepts. A low understanding of a concept makes students make their own sense of the concept (Suparno, 1998). Misconceptions have been recognized as the main factor affecting students' understanding of science in secondary level school (Coll & Tregust, 2003), even teachers have certain misconceptions as well (Burgoon et al., 2011).

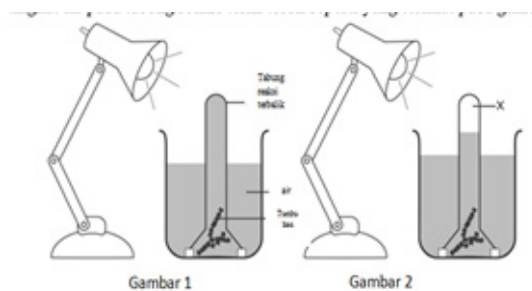
The opinion-based judgment error in this study could be found on this question: *“Explain why your heart beats faster when you exercise.”*

Students' answer was "If we do many movements, then our heart will rate faster caused by active organs". The answer shows that the opinion or the corresponding answer seemed to be true without linking to the known biological concepts about how much oxygen required when exercising, resulting in faster heart pump to meet the needs of oxygen in the body.

### Contradiction Error

The mistake of contradiction relates to the error by stating two different ideas that conflicting to each other. Some students make choices and reasons for their answers in accordance with what is ordered on the question but ultimately the reasoning is contrary to the choices given in the answer. This can happen because of misconceptions experienced by students. A misconception is an inaccurate notion of the concept, the classification of false examples, the confusion of different concepts and the hierarchical relationships of concepts that are not correct [16]. Thus, misconceptions lead students developed erroneously and different from scientifically accepted concept (Kose, 2008; Yasri, 2014).

In this study, contradiction error could be found in this question: *“The picture shows how a student set up some apparatus in a laboratory for an investigation. The inverted test tube was completely filled with water at the beginning of the investigation as shown in Figure 1. After several hours, the water level of the test tube had gone as shown in Figure 2.”*



What is the content of the top part of the test tube labeled X in Figure. 2?

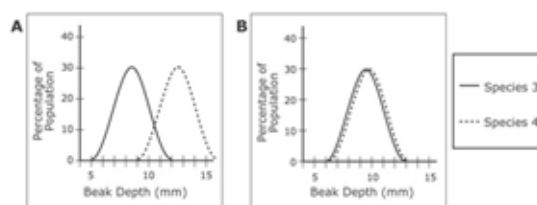
- air
- oksigen
- carbon dioxide
- vacuum

Explain your answer."

Students' answer was "Oxygen, because the water is made for photosynthesis, and because there is a light", which is correct. Plants produce oxygen at the time of photosynthesis, but in the next statement "yes because the water is made for photosynthesis and because there is a light" this reason is not related to the first statement given by students about photosynthesis.

### Disregarding Evidence Error

The rare error made was disregarding evidence. It occurs when the students fail to demonstrate the use of evidence in some of the problems including the data in question or in visual representation. Whereas this data can be used later to help the students choose the best option but many students do not give an indication that they are considering the data (Suparno, 1998). "Two other species (species 3 and 4 species) live on the Santa Maria island. which also has a range of seed types. Which of the following graphs shows a range of break depths for species 3 and species 4 that would best ensure the survival of both species on the Santa Maria island?"



Explain why this range of the beak depths is best."

Student's answer was "B. because the size of the beak is equal to the population". It seems that students ignored the other graphs and considered only one graph so they chose the wrong one. However, by choosing the wrong graphs,

students were able to find out new information about finch birds' ability to survive considering the number of different foods and the size of beaks.

This error occurs when students do not use some or all available data. For example, by using only one diagram given to the problem as a comparison. The students tended to ignore some of the data and only focused on the data he or she saw, resulting in the wrong answer. Drawn from the teachers' interview, problems or questions using comparison chart or diagram were rare.

Overall, the result showed that misreading error was the highest. This result is in accordance with Djarod et al., (2015) and Rahmat (2017). Their research of students' error in answering Physics questions indicated that the misreading was the usual error. Students are under stress when they are reading exam questions due to time monitoring and answer managing. Thus, they are more easily distracted by irrelevant ideas and less capacity available to focus on the task. This condition will lead to misreading and misinterpretations more likely (Kiwani et al., 2000).

### CONCLUSION

In sum, the most common error made by students was misreading errors due to carelessness in reading, which affected the students in selecting the wrong answer. While the rarest error type performed by students was disregarding evidence error; it was because students did not use some or all of the data available in the problem. This study also revealed that identifying students' error is crucial as the initial step to overcome students' difficulties and to improve teaching and learning in science.

### REFERENCES

- Akili, M. (2015). Regression Levels of Selected Affective Factors on Science Achievement: a Structural Equation Model with TIMSS 2011 Data. *Electronic Journal of Science Education*, 19(1), 1-16.
- Anggraini, N., & Wasis. (2014). Pengembangan Soal IPA-Fisika Nodel TIMSS (Trends In International Mathematics and Science Study). *Jurnal Inovasi Pendidikan Fisika (JIPF)*, 3(1), 15-18.
- Arslan, H. O., Cigdemoglu, C., & Moseley, C. (2012). A Three-Tier Diagnostic Test to Assess Pre-Service Teachers' Misconceptions About Global Warming, Greenhouse Effect, Ozone Layer Depletion, and Acid Rain. *International Journal of Science Education*, 34(11), 1667-1686.
- Batanero, C., Godino, J. D., Vallecillos, A., Green, D. R., & Holmes, P. (1994). Errors and difficulties

- in understanding elementary statistical concepts. *International Journal of Mathematical Education in Science and Technology*, 25(4), 527-547.
- Brodie, K. (2014). Learning about Learner Errors in Professional Learning Communities. *Educational Studies in Mathematics*, 85(2), 221-239.
- Burgoon, J. N., Heddle, M. L., & Duran, E. (2011). Re-examining the Similarities between Teacher and Student conceptions about physical science. *Journal of Science Teacher Education*, 22(2), 101-114.
- Busyairi, A., & Sinaga, P. (2015). Strategi Pembelajaran Creative Problem Solving (CPS) Berbasis Eksperimen untuk Meningkatkan Kemampuan Kognitif dan Keterampilan Berpikir Kreatif. *Jurnal Pengajaran MIPA*, 20(2), 133-143.
- Coll, R. K., & Treagust, D. F. (2003). Investigation of Secondary School, Undergraduate, and Graduate Learners' Mental Models of Ionic Bonding. *Journal of Research in Science Teaching*, 40(5), 464-486.
- Djarod, F. I., Wiyono, E., & Supurwoko, S. (2015, September). Analisis Kesalahan dalam Menyelesaikan Soal Materi Pokok Termodinamika pada Siswa Kelas XI SMA Al Islam 1 Surakarta Tahun Ajaran 2013/2014. In *PROSIDING: Seminar Nasional Fisika dan Pendidikan Fisika* (Vol. 6, No. 6).
- Gierl, M. J. (2007). Making Diagnostic Inferences About Cognitive Attributes Using the Rule-Space Model and Attribute Hierarchy Method. *Journal of Educational Measurement*, 44(4), 325-340.
- Johar, R. (2013). Domain Soal PISA untuk Literasi Matematika *Jurnal Peluang*, 1(1), 30-41.
- Kiwan, D., Ahmed, A., & Pollitt, A. (2000). *The effects of time-induced stress on making inferences in text comprehension* (Doctoral dissertation, University of Bristol).
- Köse, S. (2008). Diagnosing Student Misconceptions: Using Drawings as a Research Method. *World Applied Sciences Journal*, 3(2), 283-293.
- Markawi, N. (2015). Pengaruh Keterampilan Proses Sains, Penalaran, dan Pemecahan Masalah terhadap Hasil Belajar Fisika. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, 3(1), 11-25.
- Marlina, R., Puspaningrum, H., & Hamdani, H. (2017). Differentiation of Test Items between The High School Biology Olimpiad in North Kayong and The National Science Olimpiad. *Jurnal Pendidikan IPA Indonesia*, 6(2), 245-251.
- Mullis, I. V., Martin, M. O., Minnich, C. A., Stanco, G. M., Arora, A., Centurino, V. A., & Castle, C. E. (2012). *TIMSS 2011 Encyclopedia: Education Policy and Curriculum in Mathematics and Science. Volume 1: AK*. International Association for the Evaluation of Educational Achievement. Herengracht 487, Amsterdam, 1017 BT, The Netherlands.
- Natalia, T., & Subanji, S. (2016). Miskonsepsi pada Penyelesaian Soal Aljabar Siswa Kelas VIII Berdasarkan Proses Berpikir Mason. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, 1(10): 1917-1925.
- Patton, M. Q. (1990). *Qualitative evaluation and research methods*. SAGE Publications, inc.
- Prevost, L. B., & Lemons, P. P. (2016). Step by Step: Biology Undergraduates' Problem-Solving Procedures during Multiple-Choice Assessment. *CBE-Life Sciences Education*, 15(4), 71-85.
- Lim, K. S. (2010). An error analysis of Form 2 (Grade 7) students in simplifying algebraic expressions: A descriptive stud. *Electronic Journal of Research in Educational Psychology*, 8(1), 139-162.
- Rahmat, A. (2017). Analisis Kesalahan Siswa dalam Menyelesaikan Soal-soal pada Materi Hukum Kirchoff di Sman 1 Meranti. *Jurnal Pendidikan dan Pembelajaran*, 6(10), 2-16.
- Suharsimi, A. (2009). *Dasar-dasar evaluasi pendidikan*. Jakarta: Bumi Aksara.
- Suparno, S. J. (1998). Miskonsepsi (Konsep Alternatif) Siswa SMU dalam Bidang Fisika. *Yogyakarta: Kanisius*.
- Yasri, P. (2014). A Systematic Classification of Student Misconceptions in Biological Evolution. *International Journal of Biology Education*, 3(2), 31-41.



## INTEGRATING SQ4R TECHNIQUE WITH GRAPHIC POSTORGANIZERS IN THE SCIENCE LEARNING OF EARTH AND SPACE

T. Djudin\*<sup>1</sup> and R. Amir<sup>2</sup>

<sup>1</sup>Physics Education Department of Education and Teacher Training Faculty,  
Tanjungpura University, Pontianak, Westkalimantan-Indonesia

<sup>2</sup>Department of Innovation in Teaching and Learning,  
Faculty of Education, UK Malaysia

DOI: 10.15294/jpii.v7i1.11581

Accepted: December 19<sup>th</sup>, 2017. Approved: February 20<sup>th</sup>, 2018. Published: March 19<sup>th</sup>, 2018

### ABSTRACT

This study examined the effect of integrating SQ4R reading technique with graphic post organizers on the students' Earth and Space Science learning achievement and development of metacognitive knowledge. The pretest-posttest non-equivalent control group design was employed in this quasi-experimental method. The sample which consists of 103 seventh grade of secondary school students of SMPN 1 Pontianak was drawn by using intact group random sampling technique. An achievement test and a questionnaire of Reading-Self Awareness were administered. The findings assert that there are significant difference of students' achievement ( $F=5.594$ ,  $p < 0.05$ ) and development of metacognitive knowledge ( $F= 13.906$ ,  $p < 0.05$ ) among groups after having received the three distinctive treatments. Integrating SQ4R reading technique with graphic post organizers reveals an effective impact on the academic achievement ( $ES= 0.69$ ) and the metacognitive knowledge in reading text ( $ES = 0.48$ ). It confirms that a science teacher has to execute and model metacognitive strategies intentionally.

© 2018 Science Education Study Program FMIPA UNNES Semarang

**Keywords:** reading in science, achievement, metacognition

### INTRODUCTION

In this twenty-first century, the world is changing rapidly. It is unrealistic to prepare a literate science-information-technology people in the future if based only on facts and concepts of the content areas that students acquired during school years. A new situation and problem they faced in their daily lives required appropriate and satisfactory solutions. Fogarty (1994) confirmed that metacognitive skills are needed when habitual responses are not successful. The hub of school is an ideal place to develop students' metacogniti-

ve skills. The task of educators is to acknowledge, cultivate, exploit, and enhance the metacognitive capabilities of all learners. Ellis and Bond (2014) noted that although a large body of literature exists on metacognition, however, there are few studies that summarize specific instructional practices for improving students' metacognitive thinking.

Metacognition is the central aims of current research (Zohar & Barzilai, 2013; Jiang & Grabe, 2017) and the core objectives of science teaching and learning (Coll, et al., 2005; Mitchell, 2015). The call for developing metacognitive skills in the school disciplines is also stated explicitly in the Curriculum 2013 presently implemented in

\*Correspondence Address:  
E-mail: tomo.djudin@yahoo.com

Indonesia. Fadel, et.al. (2016) argued that metacognition plays a central role in learning and achievement. Metacognitive strategies are powerful tools for any discipline, inter-discipline or for learning in general. Teachers in classrooms may model and teach as well as teach and encourage metacognitive activity including reading a text and writing notes (Carin & Sund, 1989; Spiegel & Barufaldi, 1994; Glynn & Muth, 1994).

Spiegel & Barufaldi (1994) reported that training students on metacognitive strategies in reading and making self-notes of graphic post organizers during secondary school physics class could enhance recalls and retentions and students' achievement as well. Koch (2001) concluded that the experimental group using the Koch-Eckstein technique with the metacognitive tasks attained significantly higher score on a test of reading-comprehension physics text than those of the control group after the experimental manipulation. Based on this result, she strongly recommended that the metacognitive technique be developed and applied in teaching reading comprehension of physics texts as an effective self-monitoring device.

Although textbooks are major sources of learning, many students in schools had difficulty to gain a deep understanding of the text they read. The difficulty in understanding textbook was due to a lack of knowledge about techniques of reading and making good notes (Laidlaw, et al., 1993; Spiegel & Barufaldi, 1994). When further explored, the lack of training and guidance provided by teachers at school can be suspected as one of the "roots" of the cause. Tobias (1990) in Halloun (1996) reported that many students in school even in college forgot quickly and did not get much information from the text they read. Students who are not skilled at reading textbooks, according to Holliday et al. (1994), will only spend a lot of time unproductively. In fact, they also can not solve the problems related to the text reading.

Earth and Space is a topic in Secondary School Physics Curricula. Subject matters of this topic are mainly declarative knowledge. The use of symbols, formulas, equations, diagrams, etc during lesson period are few. Kuhn and Dean (2004) characterize declarative knowledge broadly as epistemological understanding, or the student's understanding of thinking and knowing in general. Understanding of subject matters involves the ability to read the text meaningfully.

In the context of this study, students' negative symptoms of seventh grade of public secondary school SMPN 1 Pontianak occurred while learning Earth and Space. They lacked indepen-

dence and confidence about the subject matters they learned, got bored when reading textbooks, and quickly forgot the essential information they have read or learned. The success of rate in academic achievement of this topic does not reach the minimum standard of passing rate i.e 75 % per class. The percentage of classes with passing rate less than 75 % is still quite low. This issue becomes a focus to the teacher.

One of reading techniques which can be used to enhance students' academic achievement in any subject matter (discipline) and to develop metacognitive knowledge in reading text is SQ4R (Survey, Question, Read, Reflect, Recite, Review) developed by E.L Thomas & H.A Robinson in 1972 (Glynn & Muth, 1994). This SQ4R reading technique will be more effective if it is integrated with graphic post organizers made after any reading activity. Spiegel & Barufaldi (1994) explained that any form of two-dimensional graphics, figures, or diagrams, etc. constructed by students after reading texts was called graphic post organizers. Based on the meta-analysis of 23 experimental studies, Moore & Readance (1984) in Spiegel & Barufaldi (1994) reported that making notes in any form of graphic organizers increased students' recall, retention, and concept comprehending or information in texts they read.

The main purpose of this study was to examine the extent of effectiveness of integrating SQ4R reading technique with graphic postorganizers on the students' achievement in learning Earth and Space and development of metacognitive knowledge in reading text.

## METHODS

The pretest-posttest, non-equivalent control group design was used in this quasi-experimental method (Creswell, 2008). The target population of this research was the seventh grade (11 until 14 years old) of secondary school students of public junior high school SMPN 1 Pontianak, West Kalimantan, Indonesia (N= 267) enrolled in the academic year 2013/2014 first semester. The intact group random sampling technique was applied to determine groups of sample volunteered students (35 students of class I-H as experimental group 1, 33 students of class I-D as experimental group 2, and 35 students of class I-A as the control group). Data for experimental and control groups were pooled in the same semester. The students who were absent during training or data collection were excluded from data analysis.

The independent variable was treatments which applied to the three groups. The treatments reflected the research questions were as follows : (1) *Treatment 1*: Reading Earth and Space texts by using SQ4R technique and integrating with active construction of graphic postorganizers of the text and/or of mnemonics. This treatment was applied to experimental group 1; (2) *Treatment 2*: Reading Earth and Space texts by using SQ4R technique without training of constructing of graphic postorganizers of the text. This treatment was applied to experimental group 2; (3) *Treatment 3*: Teaching-learning process of Earth and Space text by using lecturing (conventional) method. No training of SQ4R reading technique was employed. This treatment was applied to control group.

To execute operationally the SQ4R reading technique in teaching-learning process of entire materials of Earth and Space in the classroom, the procedures are as follows: (1) *Surveying*, checking title, heading, subheading in textbook they read as guidance; (2) *Questioning*, making or asking her/himself some (written) questions related to contents or material contained in reading text; (3) *Reading*, reading for understanding (that can be assisted or monitored by the questions student made) by signing, underlining, bolding, highlighting, etc on the essential information while reading text; (4) *Reflecting*, considering the information have read for answering questions and relating the information to his/her own prior knowledge; (5) *Reciting*, answering the questions; (6) *Reviewing*, organizing the information of reading text into graphic post organizers and/or mnemonics (e.g: acronym, peg-type, and loci-type).

The first dependent variable was the overall score on pre-and posttest of students' achievement in learning Earth and Space collected by administering 10 items of completion (recall) test, 13 items of four options multiple-choice (comprehending) test and 5 items of essay (application) test. The reliability coefficient of point-biserial correlation for Earth and Space Science learning achievement test was 0.62.

The second dependent variable was the score on pre-and posttest of students' development of metacognitive knowledge in reading text. Costa (1985) argued that metacognitive instruction would include learning how to learn; how to study for a test; how to use strategies of asking before, during, and after reading. It might include how to learn best—visually and diagrammatically. Metacognitive knowledge in reading the text was assessed by using 22 items of Questionnaire of Index of Reading-Self Awareness with four alternative responses (always, often, sometimes, and never) concerning what students do before, during, and after reading (in Appendix 1). This questionnaire was developed by adopting Index of Reading Awareness (McLain, et al., 1991) and Metacognitive Self-Assessment (Gaskin, et al., 1994). The items distinction power were entirely significant ( $2.402 < t < 7.538$ ). The qualitative expert judgments to seek content validity was administered as well.

Comparisons (t-test and F-test,  $< 0.05$ ) made among the three groups showed a significant difference in the scores of students' Earth and Space Science learning achievement and of metacognitive knowledge in reading the text. The extent of effectiveness of integrating SQ4R reading technique was assessed by using the Effect Size (Cohen, 1988), namely  $ES = \frac{\text{difference between the means, } M_1 - M_2}{\text{standard deviation of either group}}$ .

## RESULTS AND DISCUSSION

### Pretest

Interval data (scores) gathered from the three groups were analyzed by using F-test (One-Way ANOVA). Pretesting concluded that there were no significant difference scores of academic achievement of Earth and Space topic between experimental groups (group 1 and 2) and control group ( $F = 0.074$ ,  $\text{sig} = 0.929$ ,  $p > 0.05$ ) as shown in table 1. The same results, there was no significant difference scores of metacognitive knowledge in reading the text ( $F = 0.039$ ,  $\text{sig} = 0.962$ ,  $p > 0.05$ ) as shown in table 2.

**Table 1.** Pretest Mean of the Students' Academic Achievement in Learning Earth and Space

Group	N	Mean	SD	df	F value	Sig
Experimental 1	35	32.84	7.86			
Experimental 2	33	32.49	9.05	2	0.074	0.929
Control	35	32.16	8.58			



**Table 2.** Pretest Mean of Metacognitive Knowledge

Group	N	Mean	SD	df	F value	Sig
Experimental 1	35	26.29	5.92			
Experimental 2	33	26.37	5.79	2	0.039	0.962
Control	35	26.64	7.18			

The result shows that there were no significant differences between students' academic achievement of Earth and Space topic and metacognition knowledge of the students in reading text before making the manipulation of the treatments in this study. Therefore, post hoc Scheffe-test was not necessary to be carried out by the researcher.

#### Posttest Means of Students' Achievement on Earth and Space Topic

Comparisons of means in posttest between the experimental groups (group 1 and 2) and control group showed significant differences of students' academic achievement on Earth and Space ( $F = 5.594$ ,  $sig = 0.005$ ,  $p < 0.05$ ) as shown in table 3.

**Table 3.** Posttest Means of the Students' Academic Achievement in Learning Earth and Space

Group	N	Mean	SD	df	F value	Sig
Experimental 1	35	66.27	14.66			
Experimental 2	33	63.07	15.32	2	5.594*	0.005
Control	35	56.67	13.60			

\* Significant at the 0.05 level

The result showed that integrating SQ4R reading technique with graphic post organizers brought the about significant difference in academic achievement in learning Earth and Space

between those three distinctive treatments. Due to the significant difference between the three groups were found, post hoc test by using Scheffe-test should be used and shown in table 4.

**Table 4.** Post Hoc Scheffe-test of Posttest Means of Dependent Variable 1

Dependent Variable 1	Group (I)	Group (J)	Mean difference (I-J)	Sig
Achievement score of Earth and Space Science	Experimental 1	Experimental 2	3.20	0.588
		Control	9.60*	0.006
	Experimental 2	Experimental 1	-3.20	0.588
		Control	6.40	0.092
	Control	Experimental 1	-9.60*	0.006
		Experimental 2	-6.40	0.006

\*The mean difference is significant at the 0.05 level

From tabel 4, the research findings were as follows: (1) There was no significant difference of increasing students' academic achievement in learning Earth and Space topic between experimental group 1 and experimental group 2 ( $> 0.05$ ); (2) There was significant difference of increasing students' academic achievement in learning Earth and Space topic between experimental group 1 and control group ( $< 0.05$ ); (3)

There was no significant difference of increasing students' academic achievement in learning Earth and Space topic between experimental group 2 and control group ( $> 0.05$ )

The result shows that the effectivity of integrating SQ4R reading technique with graphic post organizers on increasing students' academic achievement in learning Earth and Space topic was higher than that of SQ4R reading technique

and lecturing (conventional) method. The extent of effectiveness was shown by mean effect size = 0.69 (in effective category).

Spark Student Paper and Academic Research Kit (2014) confirmed that SQ4R is an effective strategy to help all students get the information that they need from textbooks. It works for average, learning disabled, and gifted students whether they are in elementary school or college. There are variations to this strategy, including SQ3R, SRR, and PQ4R, that involve more or fewer steps. This method can be used for reading any type of material at any stage of the research assignment. However, when the text does not appear to be organized according to one of the patterns or text structures, students must create a visual they can use to take notes while or after reading to explore the relationships among the ideas in the text. Using graphic organizers also helps students to see connections as they construct their understanding of science concepts. Using SQ4R methods in language domains was effective to increase students' comprehension of the generic structure of the text and the meaning of words (Yakupoglu, 2012; Raharjo, et al., 2013; Hanani, et al., 2015). For example, Raharjo et al. (2013) concluded that SQ4R strategy is an appropriate strategy to increase students' achievement in reading comprehension of recount text. The use of semantic and schema mapping was recommended to increase the SQ4R effectivity.

Reading comprehension of texts is a neglected area in physics curricula. Rote learning is the only one learning strategy commonly employed by many teachers. I found that just a few science teachers trained their students explicitly the reading strategy and making graphic post organizers to gain deep understanding and retention. In addition, they did not intentionally model the learning strategy for developing students' metacognition in their classroom. Many science teachers assume that how to read textbooks meaningfully for gaining comprehension and increasing students' academic achievement should be trained by language teachers. Many are unaware of the importance of metacognitive knowledge development in the teaching-learning as well. Painscar et al. (1996) stated that for students to gain understanding, teachers need to use a variety of reading strategies, including those that involve manipulative, interactive, and physical materials, to address science content in depth and avoid focusing on isolated or disconnected facts" (p.123).

Rasinki and Padak (2004) confirmed that most students arrive at the science teacher's classroom knowing how to read, but few understand how to use reading for learning science content.

Barton & Jordan (2001) confirmed that reading is not only a crucial way for students to learn science content, it is also an important part of what professional scientists actually do. One study found that scientists and engineers spend over half of their working time reading, interpreting, and producing text. Without research, there is no science; but without communication, research would grind to a halt. Literacy enables vital inputs and outputs for research: read; research; write; repeat. Armbruster et al. (1989) supported this notion. He said that many educators contend that when students *do* science, they are more engaged in learning than when they read science text. In fact, reading science text and textbooks requires the same critical thinking, analysis, and active engagement as performing hands-on science activities. Science and reading have many process skills in common. The same skills that make good scientists also make good readers: engaging prior knowledge, forming hypotheses, establishing plans, evaluating understanding, determining the relative importance of information, describing patterns, comparing and contrasting, making inferences, drawing conclusions, generalizing, evaluating sources, and so on.

Students in science classrooms are given numerous opportunities to read the text in a variety of formats and for a variety of purposes. They read to solve a problem, understand the steps in an experiment, gain basic knowledge about a concept, answer their own questions, compare their inquiry results with what others have found, expand their basic understanding of a concept, and for enjoyment. The reading tasks going on in science classrooms today are quite extensive and do complement efforts being made in schools to improve reading achievement. However, science teachers need to support struggling readers with strategies that will enhance their comprehension of science reading materials.

#### **Posttest Means of Metacognitive Knowledge**

Comparisons of means in posttest between the experimental groups (group 1 and 2) and control group showed significant differences of students' metacognitive knowledge in reading the text ( $F = 13.906$ ,  $\text{sig} = 0.000$ ,  $p < 0.05$ ) as shown in table 5.

**Table 5.** Posttest Means of Metacognitive Knowledge

Group	N	Mean	SD	df	F value	Sig
Experimental 1	35	34.18	7.21			
Experimental 2	33	33.07	6.65	2	13.906*	0.000
Control	35	30.12	6.82			

\* Significant at the 0.05 level

The results show that integrating SQ4R reading technique with graphic post organizers brought a significant difference in the development of metacognitive knowledge between those

three distinctive treatments. Due to the significant difference between the three groups were found, post hoc test by using Scheffe-test should be used and shown in table 6.

**Table 6.** Post Hoc Test of Posttest Means of Dependent Variable 2

Dependent Variable 2	Group (I)	Group (J)	Mean difference (I-J)	Sig
Score of Metacognitive Knowledge	Experimental 1	Experimental 2	1.11	0.734
		Control	4.06*	0.045
	Experimental 2	Experimental 1	-1.11	0.734
		Control	2.95	0.045
	Control	Experimental 1	-4.06*	0.045
		Experimental 2	1.11	0.734

\*The mean difference is significant at the 0.05 level

From table 6, the research findings were as follows: (1) There was no significant difference of development of metacognitive knowledge in reading text between experimental group 1 and experimental group 2 ( $> 0.05$ ); (2) There was significant difference of development of metacognitive knowledge in reading text between experimental group 1 and control group ( $< 0.05$ ); (3) There was no significant difference of development of metacognitive knowledge in reading text between experimental group 2 and control group ( $> 0.05$ ).

The results show that the effectivity of integrating SQ4R reading technique with graphic postorganizers on development of metacognitive knowledge in reading text was higher than that of lecturing (conventional) method. The extent of effectiveness was shown by mean effect size = 0.48 (in effective category).

Glynn & Muth (1994) argued that SQ4R reading techniques will be more effective if it is integrated with graphic postorganizers made after any reading activity. Reading and writing involve thinking process (Tierney, et al., 1980; Ridley, et al., 1992). Bond et al. (1995) confirmed that lear-

ning to read and reading to learn should develop together throughout the school years. Many researchers demonstrated that writing provided a vehicle for teachers to follow students' changes in thinking as they moved from topic to topic and expressed their understanding of concepts. Students' written ideas provided a window into their thinking processes. Flavell (1987), a pioneer in the field of metacognition, mentioned a number of experiences or activities that might assist metacognitive development. Teachers in schools may sometimes model, teach and encourage metacognitive activity including reading and writing any text.

The result showed that integrating SQ4R reading technique with graphic post organizers brought a significant difference in the development of metacognitive knowledge between those three distinctive treatments. Due to the significant difference between the three groups were found, post hoc test by using Scheffe-test should be used and shown in table 6.

Thinking process involves cognition and metacognition (Costa, 1985; Livingston, 1997). Nelson (1999) stated that cognitive strategies are

different from metacognitive strategies. It is often difficult to distinguish metacognitive and cognitive. There is also much debate over what metacognition is. These terms are sometimes confusing. According to Weinert and Kluwe (1987), cognitive and metacognitive strategies may overlap in that the same strategy could be regarded as either cognitive or metacognitive depending on what the purpose of using that strategy. Maybe sometimes one reads things slowly simply to learn the contents (cognitive strategy); other times one reads through things quickly to get an idea of how difficult or easy it is going to learn the content (metacognitive strategy).

Metacognition is thinking about your thinking as you are thinking to improve your thinking (Glynn & Muth, 1994). According to Flavell (1979) in Mahdavi (2014), metacognitive knowledge refers to one's knowledge or beliefs about a person, task, and strategy variables. Metacognitive knowledge can be added, deleted, or revised through metacognitive experiences. Ertmer and Newby (1996) described that the novice learners don't stop to evaluate their comprehension of the material. They generally don't examine the quality of their work or don't stop to make revisions as they go along, and are satisfied with just scratching the surface as well. They also don't attempt to examine a problem in depth. Novice learners don't make connections or see the relevance of the material in their lives. On the contrary, expert learners are more aware than novices of when they need to check for errors, why they fail to comprehend, and how they need to redirect their efforts. Taking reading for example. We have all experienced the phenomenon of reading a page or a whole of the chapter in the textbook and then realizing we haven't comprehended a single thing. A novice learner would go on to the next page, thinking that merely reading the words on a page is enough. An expert learner would re-read the page until the main concept is understood, or flag a difficult passage to ask for clarification from teacher or peers later.

Several researchers offer evidence that metacognition is teachable (Flavell, 1987; Winn & Snyder, 1996; Kramarski & Mevarech, 2003; Schraw, et al., 2006). For example, Schraw, et al. (2006) described an intervention targeted at improving the metacognitive skills and reading comprehension of 171 students in third and fifth grades. Simpson & Nist (2000) emphasized that instructors need to provide explicit instruction on the use of study strategies. In the course of learning to read, the child gets practice in scrutinizing messages in isolation from context, and in evalua-

ting the possible intended meanings and implications. Mitchell (2015) recommended some strategies to improve students' metacognitive skills in the classroom. One of them is that teacher should be a "wrapper" to increase students' monitoring skills. A "wrapper" is a short intervention (give a few tips) that surrounds an existing activity and integrates a metacognitive practice. When used often, this activity not only increases learning but also improves metacognitive monitoring skills.

As students become more skilled at using metacognitive strategies, they gain confidence and become more strategic, more independent as learners. Independence leads to ownership as students realize they pursue their own intellectual needs and discover a world of information at their fingertips (Abromitis, 2009). Because learning how to learn, developing a repertoire of thinking processes to solve a problem, is a major goal of education, the metacognitive strategies will be a critical ingredient to successful learning. In addition, by using metacognitive strategies, students can truly learn. Teachers who use metacognitive strategies can positively impact students who have learning disabilities by helping them to develop an appropriate plan for learning information, which can be memorized and eventually routine. As students become aware of how they learn, they will use these processes to efficiently acquire new information, and consequently, become more of an independent thinker.

## CONCLUSION

It is concluded that integrating SQ4R reading technique with graphic post organizers has an effective impact on the students' academic achievement of Earth and Space topic and the development of metacognition knowledge in reading the text (mean effect size respectively 0.69 and 0.48). Reading activities of SQ4R such as constructing graphic post organizers e.g. concept maps, mnemonics, and any two-dimensional diagrams and the replete examples of their application in the Earth and Space learning bear consideration for promoting students' metacognitive knowledge. One of the important ideas this study showed was that writing or constructing notes of graphic organizers was a window for students' knowledge changes. The integrating of two learning activities may be as a mechanism for stimulating the reflection and feedback that facilitates the increase of academic achievement and development of metacognitive knowledge.

## REFERENCES

- Abromitis, B. (2009). Metacognitive strategies for K-12 students : Teaching Students to be Strategic in Thinking will Improve Learning. Retrieved from <http://teaching-Strategies-mentorship.Suite101.com/article.cfm/Metacognitive-Strategies-for-k-12-Students#xzzOf7wEC6yB>
- Armbruster, B. B., Anderson, T. H., & Ostertag, J. (1989). Teaching text structure to improve reading and writing. *The Reading Teacher*, 43(2), 130-137.
- Barton, M. L., & Jordan, D. L. (2001). *Teaching reading in science*. ASCD.
- Bond, et.al. (1994). *Reading Difficulties. Their Diagnosis and Correction*. Boston : Allyn & Bacon, Inc.
- Carin, A. A., & Sund, R. B. (1989). *Guided discovery activities for elementary school science*. Merrill Publishing Company.
- Cohen, R.(1988). Effect Size (ES). Retrieved December 4, 2012, from <http://www.uv.es/EffectSizeBecker>
- Coll, R. K., France, B., & Taylor, I. (2005). The role of models/and analogies in science education: implications from research. *International Journal of Science Education*, 27(2), 183-198.
- Costa, A.L. (1985). *Developing Minds. A Resource Book for Teaching Thinking*. Alexandria, Virginia: Association for Supervision and Curriculum Development.
- Creswell, J.W. (2008). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research* (3<sup>rd</sup> ed). Boston : Pearson Prentice Hall.
- Dirkes, M. A. (1985). Metacognition: Students in charge of their thinking. *Roeper Review*, 8(2), 96-100.
- Ellis, A.K., & Bond, J.B. (2014). An Analysis of Research on Metacognitive Teaching Strategies, *Prodia-Social and Behavioral Sciences*, 32(116), 4015-4024.
- Ertmer, P.A., & Newby, T.J. (1996). The Expert Learner : Strategic, Self-Regulated, and Reflective. *Instructional Science*, 24(5), 1-24.
- Fadel, C., Trilling, B., & Maya, B.M. (2016). Metacognitive Strategies are Powerful Tools ,for any Discipline, Inter-Discipline or for Learning in General. Retrieved July 14, 2017, from <https://ww2.kqed.org/-mindshift/2016/08/10/the-role-of-metacognition-in-learning-and-achievement/>
- Flavell, J. H. (1987). Speculations about the nature and development of metacognition. *Metacognition, motivation, and understanding*, 21-29.
- J.H. Fogarty. "Read About Best Practices in Metacognitive Strategies," Internet: <http://www.benchmarkeducation.com/leader/reading/metacognitive-strategies.html>, 1994, In Fountas & Pinnel, 2000.
- Gaskins, I. W., Guthrie, J. T., Satlow, E., Ostertag, J., Six, L., Byrne, J., & Connor, B. (1994). Integrating instruction of science, reading, and writing: Goals, teacher development, and assessment. *Journal of Research in Science Teaching*, 31(9), 1039-1056.
- Glynn, S. M., & Muth, K. D. (1994). Reading and writing to learn science: Achieving scientific literacy. *Journal of research in science teaching*, 31(9), 1057-1073.
- Halloun, I. (1996). Schematic modeling for meaningful learning of physics. *Journal of Research in Science Teaching*, 33(9), 1019-1041.
- Sada, C., & Novita, D. (2015). Improving Students' Reading Comprehension on Recount Text by Using SQ4R and Media Booklet. *Jurnal Pendidikan dan Pembelajaran*, 4(6).
- Holliday, W. G., Yore, L. D., & Alvermann, D. E. (1994). The reading-science learning-writing connection: Breakthroughs, barriers, and promises. *Journal of research in science teaching*, 31(9), 877-893.
- Inspiration Software Inc. (2017). Teaching and Learning with Graphic Organizer. Retrieved July 4, 2017, from <http://www.inspiration.com/visual-learning/graphic-organizers>
- Jiang, X., & Grabe, W. (2007). Graphic organizers in reading instruction: Research findings and issues. *Reading in a foreign language*, 19(1), 34-55.
- Kementerian Pendidikan dan Kebudayaan. (2013). *Peraturan Menteri Pendidikan dan Kebudayaan Republik Indonesia Nomor 54 Tahun 2013 tentang Standar Kompetensi Lulusan Pendidikan Dasar dan Menengah*. Jakarta : Pustaka Nasional.
- Kramarski, B., & Mevarech, Z. R. (2003). Enhancing mathematical reasoning in the classroom: The effects of cooperative learning and metacognitive training. *American Educational Research Journal*, 40(1), 281-310.
- Koch, A. (2001). Training in Metacognition and Comprehension of Physics Texts, *Science Education*, 85 (6), 758-768.
- Kuhn, D., & Dean, Jr, D. (2004). Metacognition: A bridge between cognitive psychology and educational practice. *Theory into practice*, 43(4), 268-273.
- Livingston, J. A. (1997). Metacognition: An Overview. Retrieved July 4, 2017 from <http://www.gse.buffalo.edu/jas/shuell/CEP564/Metaeog.htm>.
- Mahdavi, M. (2014). An overview: Metacognition in education. *International Journal of Multidisciplinary and Current Research*, 2, 529-535.
- McLain, K. V. M., Gridley, B. E., & McIntosh, D. (1991). Value of a scale used to measure metacognitive reading awareness. *The Journal of Educational Research*, 85(2), 81-87.
- Mitchell, M.P. (2015). Metacognition: Nurturing Self-Awareness in The Classroom. Retrieved July 12, 2017, from <https://www.edutopia.org/blog/8-pathways-metacognition-in-classroom-marilyn-price-mitchell>
- Nelson, T. O. (1999). Cognition versus Metacognition. In RJ Sternberg. *The Nature of Cognition* (pp. 625-641). Cambridge: MIT Press.

- Palinscar, et.al. (1986). *Teaching Reading as Thinking*. Alexandria, VA: Association for Supervision and Curriculum Development.
- Raharjo, et al. (2013). The Effectiveness of Using SQ4R (Survey, Question, Read, Record, Recite, Review ) Method To Improve Students Ability In Reading Narrative Text At The Tenth Grade Students Of SMAN 2 Purworejo In The Academic Year Of 2012/2013. *SCRIPTA English Research Articles*, 2(3), 12-15.
- Rasinski, T. V., & Padak, N. (2004). *Effective reading strategies: Teaching children who find reading difficult*. Prentice Hall.
- Ridley, D. S., Schutz, P. A., Glanz, R. S., & Weinstein, C. E. (1992). Self-regulated learning: The interactive influence of metacognitive awareness and goal-setting. *The journal of experimental education*, 60(4), 293-306.
- Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. *Research in science education*, 36(1-2), 111-139.
- Spark Student Paper and Academic Research Kit (2017). Retrieved August 2, 2017, from [https://www.southwesterncc.edu/.../SQ4R\\_Reading\\_Process.pdf](https://www.southwesterncc.edu/.../SQ4R_Reading_Process.pdf)
- Spiegel, G. F., & Barufaldi, J. P. (1994). The effects of a combination of text structure awareness and graphic postorganizers on recall and retention of science knowledge. *Journal of Research in Science Teaching*, 31(9), 913-932.
- Swinson, K. (1992). Writing Activities as Strategies for Knowledge Construction and the Identification of Misconceptions in Mathematics. *Journal of Science and Mathematics Education in Southeast Asia*, 15(2), 7-14.
- Tierney, et.al. (1980). *Reading Strategies and Practices : Guide for Improving Instruction*. Boston: Allyn and Bacon, Inc.
- Winn, W., & Snyder, D. (1996). Cognitive Perspectives in Psychology . In D.H. Jonassen, ed. *Handbook of Research for Educational Communications and Technology*. (pp. 112-142). New York: Simon & Schuster Macmillan.
- Weinert, F. E., & Kluwe, R. H. (1987). Metacognition, motivation, and understanding.
- Yakupoglu, F. (2012). The effects of cognitive and metacognitive strategy training on the reading performance of Turkish students. *Practice and Theory in Systems of Education*, 7(3), 353-358.
- Zohar, A., & Barzilai, S. (2013). A review of research on metacognition in science education: Current and future directions. *Studies in Science Education*, 49(2), 121-169.



## DO PHYSICS TEXTBOOKS PRESENT THE IDEAS OF THOUGHT EXPERIMENTS?: A CASE IN INDONESIA

H. Bancong<sup>\*1,2</sup> and J. Song<sup>3</sup>

<sup>1</sup>Physics Education Department, Universitas Muhammadiyah Makassar, Indonesia

<sup>2</sup>Graduate Program of Physics Education, Seoul National University, South Korea

<sup>3</sup>Center for Educational Research, Seoul National University, South Korea

DOI: 10.15294/jpii.v7i1.12257

Accepted: December 5<sup>th</sup>, 2017. Approved: February 16<sup>th</sup>, 2018. Published: March 19<sup>th</sup>, 2018

### ABSTRACT

This study sought to check and evaluate whether or not thought experiments presented in the Indonesian physics textbooks can be used as tools to transfer scientific knowledge. This was a descriptive study using Indonesian physics textbooks as the primary sources of data. In this study, we analyzed thirty (30) physics textbooks from Grades 10 to 12 which are widely used both by teachers and students. The results showed that majority of physics textbooks did not mention about thought experiments. Only 6 physics textbooks presented thought experiments at a satisfactory level. The number of physics textbooks that described thought experiments in fair and poor levels are 9 and 5 respectively. The study concludes that Indonesian physics textbooks published from 2009 to 2017 generally lack thought experiments. Many authors of these Indonesian physics textbooks ignored or inadequately present thought experiments. Moreover, 70% of thought experiments mentioned in the physics textbooks were in the fair and poor levels. So, in general, thought experiments presented in the Indonesian physics textbooks cannot be used as an introduction in transferring scientific knowledge to science students.

© 2018 Science Education Study Program FMIPA UNNES Semarang

**Keywords:** Indonesia, physics textbook, thought experiments

### INTRODUCTION

Thought Experiment (TE) in the field of physics plays important roles in constructing scientific theories. Many famous scientists used TEs either to represent their views in formulating a new theory or to show the weakness of an existing theory as well as to destroy a common theory (Brown, 1986; Duhem, 1990; Reiner, 1998; Cooper, 2005). Without TEs, the theory of relativity would not have been possible as Einstein and Infeld (1938) argued that the ideal experiments created by thought greatly helped them in formulating the theory of relativity which is

possible by simple methods. Due to its essential role, some researchers have been paying attention to the TEs in the area of science education, especially physics. There are several studies that have explored the role of TEs in the teaching and learning physics. For example, the study of Lattery (2001) indicated that the use of TEs creates a fruitful discussion and even helps students generate well-rationalized hypothesis for their experiments. Other studies showed that TEs could improve active engagement and may help students to mentally construct (Lattery, 2001; Klassen, 2006; Velentzas & Halkia, 2013). Furthermore, TEs can help the students recognize the scientific thinking and understand physics concepts better (Gilber & Reiner, 2000; Reiner & Gilber, 2004; Velent-

\*Correspondence Address:

E-mail: hartono.b.b@unismuh.ac.id

zas et al., 2007; Ince et al., 2016). TEs can also expose students' hidden reasoning and improve students' inquiry skills through thinking processes (Clement, 2009; Kosem & Ozdemir, 2014). Some researchers also suggest that physics teachers and even in-service physics teachers familiarize their students with TEs when teaching physics at school (Reiner & Burko, 2003; Galili, 2009; Asikainen & Hirvonen, 2014). Thus, TEs seem to be very important especially in the teaching and learning of physics.

Trying to understand how TEs are presented in the general physics textbooks, Gilbert & Reiner (2000) studied and focused on three popular physics textbooks. One of them, the *Understanding Physics for Advanced Level* written by Breithaupt was intended for 16-18 year-olds in high schools in England and Wales. The other two, *Physics (2nd edition)* written by Ohanion and *Conceptual Physics (7th edition)* written by Hewitt are widely used in first-year university courses in the USA and elsewhere. The results show that the popular physics textbooks often miss the opportunity to introduce TEs even though there are various reasonable opportunities to do so. Moreover, TEs in those textbooks often transform into thought simulations. Gilbert & Reiner (2000) argued that the writers of these popular physics textbooks may not understand the actual potential of using TEs. In fact, TEs can be a fruitful approach to enhance students' cognitive engagement in the learning process.

On the other hand, Velentzas et al. (2007) specifically investigated the presence of TEs on the theory of relativity and quantum mechanics in both physics textbooks and popular science books. There were ten textbooks and fifteen popular science books in their study. The physics textbooks that they analyzed were mostly from university books and only one Greek textbook from high school. The popular science books were addressed to the general public. The results showed that the authors of both physics textbooks and popular science books considered TEs as an essential tool in the presentation of the theory of relativity and quantum mechanics (Velentzas et al., 2007).

Although there have been studies that specifically examined TEs in physics textbooks, most of the textbooks were for university level. Analysis of school textbooks in relation to TEs has not been extensively conducted by the education community, whereas students need to be introduced to TEs early in the school. In this way, physics textbooks play a major role becau-

se physics teachers today still often teach physics based on the textbook (Levitt, 2002). The school textbooks are not only easily accessible but can also support each student's learning style (Ogan-Bekiroglu, 2007). Teachers should consider that students have their own learning style (Watson & Thomson, 2001; Denig, 2004) as well as thinking style (Watson & Thomson, 2001; Pintrich, 2002; Bancong & Subaer, 2013, 2015) in order to teach physics.

Analysis of the content related to TEs in physics textbooks would provide a good indication showing how much of TEs are taught in the schools. In this study, we explored TEs present in the Indonesian physics textbooks and evaluated whether they are necessary or not to serve as a tool to transfer scientific knowledge to students. So, the research questions in our study were: (1) How frequent and what kind of TEs are present in Indonesian physics textbooks? (2) How did the authors present TEs in Indonesian physics textbook? (3) Can the TEs present in Indonesian physics textbooks be used as an introduction in transferring scientific knowledge?

## METHODS

This research used the descriptive method to describe the real situation of TEs presented in Indonesian physics textbooks. In this study, 30 physics textbooks published and used from grade 10 to 12 in Indonesia were analyzed. Physics textbooks published by the Ministry of Education were the main focus (BSE physics textbooks). However, the analysis also was carried out on several physics textbooks which became available through government approval (Non-BSE physics textbooks). According to Mukaromah & Suparwoto (2016), there is no difference between the contents BSE and Non-BSE physics textbooks. The guidelines for selecting physics textbooks were: (1) written based on 2006 Curriculum or 2013 Curriculum; (2) widely used by teachers and students; and (3) published by well-known book publishers.

There were eight TEs evaluated in this study. These eight TEs were based on the content of standards of competencies from the Indonesian National Curriculum. The evaluation of TEs was done for both 2006, and 2013 curricula since some schools in Indonesia still use the old 2006 curriculum. The contents of TEs related to the standard competencies from Indonesian National Curriculum are shown in table 1.



**Table 1.** The content of TEs related to standard of competencies from Indonesian

No	Grade	Standard of Competencies		TEs
		2006 Curriculum	2013 Curriculum	
1	10	Analyzing the physical quantities of rectilinear motion with constant velocity and acceleration	Analyzing the physical quantities of rectilinear motion with constant velocity and rectilinear motion with constant acceleration.	Galileo's free fall
2	11	Analyzing the regularity of planetary motion in the solar system according to Newton's laws.	Analyzing the regularity of planetary and satellites motion in the solar system according to Newton's laws.	Newton's canon
		Analyzing the changes in the ideal gas state by applying the laws of thermodynamics	Analyzing the changes in the ideal gas state by applying the laws of thermodynamics	Maxwell's demon
3	12	Formulating the special theory of relativity for time, length, and mass, as well as equality of mass and energy that can be applied in technology	Explaining the phenomenon of changes in the length, time, and mass associated with reference frame, equality of mass and energy in the special theory of relativity	Galileo's relativity, Einstein's chasing a light beam, Einstein's magnet and conductor, Einstein's train, Einstein's twin paradox

In order to analyze the textbooks, Niaz et al. (2013) used three classifications: satisfactory, mention, and no mention. If the textbook provides information in detail, it becomes "satisfactory" classification, while if the textbook provides information in semi-detail, then it is "mention" classification. In our views, the classification of mention is too general and widespread. Therefore, we divided the classification of mention into two sub-categories: fair and poor. So, there are four classifications used in this study: satisfactory, fair, poor, and no mention.

The three criteria we used to classify TEs in physics textbooks were: (1) background; (2) performance; and (3) results. These criteria are related to each other in conducting TEs. In our opinion, the existence of performance and results without a background would cause students not

know the history of TEs. Similarly, the existence of background and results without performance will cause the students do not recognize what TEs are. So, the following classifications used to analyze TEs in the Indonesian physics textbooks were: *satisfactory* – if TEs in physics textbooks meet all the criteria; *fair* – if TEs just meet two criteria; *poor* – if only one of the criteria is provided in the physics textbooks; and *no mention* – if the physics textbooks did not mention TEs at all.

## RESULTS AND DISCUSSION

The analysis on TEs presented in the Indonesian physics textbooks resulted in three groups based on the grade. Table 2 shows the results of TEs for Grade 10.

**Table 2.** The Results of TEs in the Indonesian Physics Textbooks for Grade 10

No.	TEs	Indonesian Physics Textbooks									
		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
1	Galileo's free fall	F	S	F	P	N	N	N	P	N	S

S: Satisfactory; F: Fair; P: Poor; N: No Mention

### Galileo's free fall

It is clear that only two of ten physics textbooks present the ideas of Galileo's free fall at the *satisfactory* level as shown in Table 2. In textbook A2, the author presented the background and performance of Galileo's free fall about the feather, and the paper dropped in a vacuum tube. The author presented the TE by assuming these objects will reach the bottom of the vacuum tube at the same time. The following is an example of TE of Galileo's free fall at the *satisfactory* level as shown in textbook A2.

*Before Galileo's time, the most of the people believed in Aristotle's ideas that heavier objects would fall faster than lighter objects. In other words, the speed of falling an object is proportional to its weight. Galileo then opposed that idea and declared that all objects would fall with the same acceleration in the absence of air or other obstacles.....To strengthen his argument, he gave an ingenious experiment. Imagine in the space where air has been sucked, light objects such as feathers or a piece of paper held horizontally will fall with the same acceleration as other heavy objects. As we know that demonstrations in a vacuum like this did not exist in Galileo's time. Nevertheless, Galileo believed that air acts as an obstacle to very light objects that have a large surface.....The results of this experiment show that all objects will fall with the same constant acceleration. For an object that falls from the rest, the distance traveled will be proportional to the square of time,  $h \approx t^2$  (Sumarsono, 2009: 45-46)*

Table 2 also shows two physics textbooks at the *fair* level. The authors presented Galileo's free fall in two ways. First, the authors explained the background and results of Galileo's free fall but did not provide the performance of that TE. Second, the authors explained the performance and result of Galileo's free fall but did not provide its background. Therefore, they cannot be used as an introduction in transferring scientific knowledge to students with the loss of one of three satisfactory criteria of TEs. The following is an example of TE of Galileo's free fall at the *fair* level as shown in textbook A1.

*In Aristotle's day, people believed that falling objects would take time depending on the mass of the object. Aristotle ar-*

*gued that objects with a larger mass would reach the ground more quickly. This view is still widely considered true by today's society who do not understand it. Yet this view of Aristotle has been opposed by Galileo (1564-1642). He was a scientist who opened a new view of the importance of experimenting..... Galileo has conducted experiments on an object in the free fall. The results show that the time needed by falling objects does not depend on its mass but depends on the height. Is Galileo's view correct? The truth can be proven by your own experiment or mathematically.*

$$h = v_0 \cdot t + \frac{1}{2}gt^2$$

$$h = 0 + \frac{1}{2}gt^2$$

$$t = \sqrt{\frac{2h}{g}}$$

(Handayani & Damari, 2009: 65)

Furthermore, two physics textbooks were describing Galileo's free fall at the *poor* level. In this level, the authors just described the result of Galileo's free fall without background and performance. Clearly, they cannot be used as an introduction to transport scientific knowledge due to the lack of the background and performance. Sadly, 40% of physics textbooks failed to present TE of Galileo in describing the theory of free fall. These physics textbooks provide free-fall equations with a few explanations.

### Newton's Canon and Maxwell's Demon

Table 3 shows the result of TEs analysis in physics textbooks for Grade 11. It is clear that the physics textbooks did not mention Newton's canon and Maxwell's demon. In fact, there could have some opportunities to introduce them. For example, TE of Maxwell's demon can be introduced to support the molecule-kinetic theory and the second law of thermodynamics. This Maxwell's demon produced several conclusions that support the gas kinetic theory, and the second law of thermodynamics thus making these theories becomes more logical.

**Table 3.** The Results of TEs in the Indonesian Physics Textbooks for Grade 11

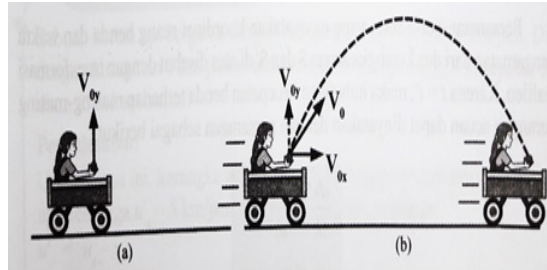
No.	TEs	Indonesian Physics Textbooks									
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
1	Newton's canon	N	N	N	N	N	N	N	N	N	N
2	Maxwell's demon	N	N	N	N	N	N	N	N	N	N

S: Satisfactory; F: Fair; P: Poor; N: No Mention

**Galileo's Relativity**

There are two physics textbooks that describe the Galileo's relativity at the *satisfactory* level as shown in Table 4. In textbook C9, for example, the authors gave a brief background of Galileo's

relativity then presented it in the form of a child riding a cart of constant speed, and throwing the ball vertically up. The authors illustrated the trajectory of the ball based on two observers in different reference frames as shown in figure 1.



**Figure 1.** The difference of trajectory of two observers in different reference frames, (a) a reference frame with constant velocity (b) a silent reference frame (Sunardi et al., 2016)

Finally, the authors described the results of Galileo's relativity in the form of mathematical equations with some explanations. This is an example of TEs at the *satisfactory* level where there are the background, performance, and re-

sults of TEs. However, there are still three TEs presented at the *fair* level and half of the physics textbooks analyzed did not mention the idea of Galileo's relativity when explaining the theory of relative speed.

**Table 4.** The results of TEs in the Indonesian physics textbooks for Grade 12

No	TEs	Indonesian Physics Textbooks									
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	Galileo's relativity	F	N	S	F	N	F	N	N	S	N
2	Einstein's chasing a light beam	N	N	N	N	N	N	P	N	N	N
3	Einstein's magnet and conductor	N	N	N	N	N	N	N	N	N	N
4	Einstein's train	N	N	P	N	P	P	N	N	N	S
5	Einstein's twin paradox	S	N	P	N	N	N	P	N	P	N

S: Satisfactory; F: Fair; P: Poor; N: No Mention

**Einstein's Chasing a Light Beam**

Einstein's chasing a light beam was the first TEs by Einstein in constructing the theory of relativity. This TE aims to test Maxwell's theory indicating a light wave in a vacuum that always propagates at the same speed with respect to the ether. Einstein then gives his TE as follows.

*"If I pursue a beam of light with the velocity c (velocity of light in a vacuum), I should observe such a beam of light as an electromagnetic field at rest though spatially oscillating. There seems to be no such thing, however, neither on the basis of experience nor according to Maxwell's equations" (Einstein, 1949:53)*

In this TE, Einstein assumed that the speed of light would be 0 when the observer is able to catch the light. Similarly, a water skier will see a

stationary wave of water when he is able to move with the water. The results of this TE emphasize that light propagates in a vacuum without a medium like a bullet fired from a rifle. Therefore, the speed of light is not always constant but depends on the reference frame of the observer.

However, none of the physics textbooks above described TE of Einstein's chasing a light beam at the *satisfactory* level. Unfortunately, this TE is very potential to be explained at the beginning of the relativity theory showing that the speed of an object is not absolute but depends on the observer's reference frame. If an observer and an object like light move together in the same speed and direction, the speed of light according to the observer is 0. However, if the observer is at rest, then the speed of light is C. This is contrary

to Maxwell's theory of electrodynamics stating that the speed of light is always equal to  $C$  in all reference frames.

### Einstein's Magnet and Conductor

None of the physics textbooks mentioned TE of Einstein's magnet and conductor as shown in Table 4. Although most physics textbooks described two postulates of Einstein, there was no detailed explanation of how these postulates were obtained. Worse yet, there were physics textbooks that stated both Einstein's postulate based on the experiment of Michelson-Morley and had misrepresented Einstein's history of constructing the theory of relativity. In fact, both Einstein's postulates (the relativity postulate and the velocity postulate) were obtained through TE of Einstein's magnet and conductor as Einstein pointed out.

*"...We will raise this conjecture (the purport of which will hereafter be called the "Principle of Relativity") to the status of a postulate, and also introduce another postulate, which is only apparently irreconcilable with the former, namely, that light is always propagated in empty space with a definite velocity  $c$  which is independent of the state of motion of the emitting body. These two postulates suffice for the attainment of a simple and consistent theory of the electrodynamics of moving bodies based on Maxwell's theory for stationary bodies" (Einstein, 1920)*

### Einstein's Train

Only one of the physics textbooks presents TE of Einstein's train at the *satisfactory* level. In textbook C10, the authors showed the contradiction of Einstein's postulate then gave TE to support that contradictory. Here is an excerpt from TE' performance in physics textbook C10.

*What if a train is moving with a speed of  $0.6c$  and emitting a beam of light with a speed of  $c$ ? According to the observer at rest in the station, the speed of light is  $1.6c$ . This result is contrary to Einstein's light postulate that stated the speed of light remains  $c$  for all observers, does not depend on the state of motion of the observer or the source (Subagya, 2017)*

Table 4 also shows 30% of physics textbooks present the idea of Einstein's train at the *poor* level. In this level, two physics textbooks only presented the result of Einstein's train without any background and performance. There was also a physics textbook that described the performance of Einstein's train by changing the content of TE, such as a train converted to an airplane.

### Einstein's Twin Paradox

Only one of the physics textbooks presents TE of Einstein's twin paradox at the *satisfactory* level. In textbook C1, the authors described the background of Einstein's twin paradox as a result of time dilation, followed by the performance of twins, one wanders into space, and another settles on the earth. Over the years, they meet again but with different ages. The authors then described how to calculate their ages as the results of that TE. So, TE of Einstein's twin paradox becomes *satisfactory* because there were background, performance, and results.

In addition, there were two ways how the authors presented the Einstein's twin paradox. First, the authors presented it in the form of problem-solving. Obviously, there was no background and experimental result. So, TE becomes *poor* level. Second, Einstein's twin paradox was presented in the form of project assignment. Here, students reviewed some literature related to Einstein's twin paradox and presented it in the classroom. The following is an example of Einstein's twin paradox in the problem-solving form as shown in the textbook C7.

There are two twin babies, A and B. Baby A remains to be rest on the earth and baby B is taken away to the spacecraft at velocity  $0.95 c$ . (a) If B is 20 years of old, how much old does A have? (b) If A is 20 years of old, how much old does B have? (Purwanto, 2009)

Based on the analysis of eight TEs in physics textbooks published and used in the Indonesian high schools today, it is clear that only a few physics textbooks introduced the idea of TEs as shown in Table 5. Only 20% of physics textbooks present Galileo's free fall and Galileo's relativity at the *satisfactory* level, and half of them did not mention Galileo's TEs.

For TE of Einstein's chasing a light beam, 90% physics textbooks did not mention it. Yet as it was mentioned earlier, this is the first TE by Einstein and became part of the special theory of relativity. TE of Einstein's train and Einstein's twin paradox are described only by one physics textbook at the *satisfactory* level. Similarly to Einstein's train, 60% physics textbooks did not mention Einstein's twin paradox. Sadly, three TEs (i.e., Newton's canon, Maxwell's demon, Einstein's magnet and conductor) were not mentioned in the Indonesian physics textbooks despite many opportunities to introduce them.

**Table 5.** The classification of TEs in the Indonesian physics textbooks

No	TEs	Classification			
		No Mention	Poor	Fair	Satisfactory
1	Galileo's free fall	4	2	2	2
2	Newton's canon	10	0	0	0
3	Maxwell's demon	10	0	0	0
4	Galileo's relativity	5	0	3	2
5	Einstein's chasing a light beam	9	1	0	0
6	Einstein's magnet and conductor	10	0	0	0
7	Einstein's train	6	3	0	1
8	Einstein's twin paradox	6	3	0	1

Table 5 also shows that there are nine TEs presented at the *poor* level and five at the *fair* level. In other words, 70% of TEs mentioned in Indonesian physics textbooks are at the *fair* and *poor* levels. In these levels, TEs cannot be used as tools to teach science knowledge due to lacking of background, performance, or results. These three elements are interrelated to each other in presenting the ideas of TEs. The presence of performance and results without a background will cause students not understand the history of TEs. Similarly, the presence of background and result without performance will cause students not know what TEs are. So, in general, TEs presented in the Indonesian physics textbooks cannot be used as an introduction in transferring scientific knowledge to science students.

Although several studies emphasized the importance of TEs in teaching and learning of physics (Lattery, 2001; Klassen, 2006; Valentzas & Halkia, 2013; Kosem & Ozdemir, 2013; Ince et al., 2016) most physics textbooks published and used in Indonesia did not present the ideas of TEs. Moreover, some physics textbooks are wrong in presenting the history of physics. For example, Einstein proposed his two postulates based on the results of the Michelson-Morley's experiment. This is not true because the two postulates of Einstein were based on the TE of Einstein's magnet and conductor. This is similar to study of Franklin (2016) that checked the historical accuracy of three experiments in physics (i.e., Robert Millikan's experiment, Michelson-Morley's experiment, and Ellis-Wooster's experiment). He found that many physics textbooks present an inaccurate history. Therefore a good teacher should be critical of what textbooks offer regarding learning and teaching of physics. Physics teachers are the decision-makers in choosing excellent textbooks for themselves as well as for their students. Teachers must have the ability in

conducting learning evaluation (Yusrizal et al., 2017) and textbooks evaluation. For that reason, physics teachers must be really selective in choosing the textbooks as a guide in teaching the scientific knowledge to their students.

The absence of TEs in physics textbooks limits both teachers and students' to understand how scientific knowledge is built, developed, and maintained by scientists. Recently, Myhreagen & Bungum (2016) reported the results from the project ReleQuant on how Norwegian physics students in upper secondary schools interpret the TEs. They argued that the lack of knowledge of TEs' history limited students' understanding of the physics concepts associated with it. Valentzas et al. (2007) also argued that students seemed to enjoy the story when learning the theory of relativity and quantum mechanics. The history of TEs presented attractively can spark students' interest in learning the concepts and principles of physics. Thus, it is necessary to teach TEs in historical perspective where there is a background, performance, and result of TEs.

TEs presented in historical perspective can be one of the most accurate tools in transferring scientific knowledge to students in the schools. It may help explain the physics concept more clearly and in detail. Further study is needed to design learning material that can accurately present TEs in physics. Collaboration between physics educators, historians, and philosophers of physics would be very useful both for making historical and epistemological roots of teaching TEs accurately and interestingly.

## CONCLUSION

This study shows that physics textbooks published from 2009 to 2017 in Indonesia generally lack TEs. None of the physics textbooks mentions TEs of Newton's canon, Maxwell's demon,

and Einstein's magnet and conductor despite the fact many opportunities could have introduced them. Only one physics textbook mentions TE of Einstein's chasing a light beam. Similar to TE of Einstein's train, Einstein's twin paradox was described by just one physics textbook at a *satisfactory* level. TE of Galileo's free fall and Galileo's relativity are described satisfactorily only by two physics textbooks.

The dissatisfaction of TEs in physics textbooks may be due to the fact that the authors have not realized the importance of TEs in the teaching and learning of physics. Many authors of the Indonesian physics textbooks ignored or inadequately presented TEs. Moreover, some of TEs were introduced in the form of problem-solving, essays, and even project assignments resulting in the loss of background and experimental results.

Finally, 70% of TEs mentioned in physics textbooks in Indonesia are at the *fair* and *poor* levels. So, in general, TEs presented in the Indonesian physics textbooks cannot be used as an introduction in transferring scientific knowledge to science students.

## REFERENCES

- Asikainen, M. A., & Hirvonen, P. E. (2014). Probing Pre- and In-service Physics Teachers' Knowledge Using the Double-Slit Thought Experiment. *Science & Education*, 23(9), 1811-1833.
- Bancong, H., & Subaer. (2013). Profil Penalaran Logis Berdasarkan Gaya Berpikir dalam Memecahkan Masalah Fisika Peserta Didik. *Jurnal Pendidikan IPA Indonesia*, 2(2), 195-202.
- Bancong, H., & Subaer. (2015). Student's Creativity Profile with Base on Thinking Model for Physics Problem Solving. *Indonesian Journal of Applied Physics*, 5(1), 1-8.
- Brown, J. R. (1986). Thought experiments since the scientific revolution. *International Studies in the Philosophy of Science*, 1(1), 1-15.
- Budiyanto, J. (2009). *Fisika untuk SMA/MA Kelas XII*. Jakarta: Pusat Perbukuan, Departemen Pendidikan Nasional.
- Clement, J. J. (2009). The Role of Imagistic Simulation in Scientific Thought Experiments. *Topics in Cognitive Science*, 1(4), 686-710.
- Cooper, R. (2005). Thought Experiment. *Metaphilosophy*, 36(3), 328-347.
- Denig, S. J. (2004). Multiple Intelligences and Learning Styles: Two Complementary Dimensions. *Teachers College Record*, 106(1), 96-111.
- Duhem, P. (1990). Logical examination of physical theory. *Synthese*, 83(2), 183-188.
- Einstein, A. (1920). On The Electrodynamics of Moving Bodies. In A. Einstein, & H. Minkowski, *The Principle of Relativity* (pp. 1-34). Kolkata: University of Calcutta.
- Einstein, A. (1949). Autobiographical Notes. In P. A. Schilpp, *Albert Einstein: Philosopher-Scientist* (pp. 2-95). New York: Tudor Publishing.
- Einstein, A., & Infeld, L. (1938). *The Evolution of Physics: The Growth of Ideas from Early Concepts to Relativity and Quanta*. Cambridge: Cambridge University Press.
- Franklin, A. (2016). Physics Textbooks Don't Always Tell the Truth. *Physics in Perspective*, 18(1), 3-57.
- Galili, I. (2009). Thought Experiments: Determining Their Meaning. *Science & Education*, 18(1), 1-23.
- Gilbert, J. K., & Reiner, M. (2000). Thought experiments in science education: potential and current realization. *International Journal of Science Education*, 22(3), 265-283.
- Handayani, S., & Damari, A. (2009). *Fisika Untuk SMA dan MA Kelas X*. Jakarta: Pusat Perbukuan, Departemen Pendidikan Nasional.
- Handayani, S., & Damari, A. (2009). *Fisika Untuk SMA dan MA Kelas XII*. Jakarta: Departemen Pendidikan Nasional.
- Handayani, S., & Damari, A. (2009). *FISIKA untuk SMA/MA Kelas XI*. Jakarta: Departemen Pendidikan Nasional.
- Haryadi, B. (2009). *Fisika untuk SMA/MA Kelas XI*. Jakarta: Departemen Pendidikan Nasional.
- Ince, E., Acar, Y., & Atakan, M. (2016). Investigation of physics thought experiments' effects on students' logical problem solving skills. *SHS Web of Conferences*, 26(1), 1-5.
- Indrajit, D. (2009). *Mudah dan Aktif Belajar Fisika*. Jakarta: Departemen Pendidikan Nasional.
- Indrajit, D. (2009). *Mudah dan Aktif Belajar Fisika*. Jakarta: Departemen Pendidikan Nasional.
- Indrajit, D. (2009). *Mudah dan Aktif Belajar Fisika*. Jakarta: Pusat Perbukuan, Departemen Pendidikan Nasional.
- Kanginan, M. (2014). *FISIKA untuk SMA/MA Kelas X*. Jakarta: Penerbit Erlangga.
- Kanginan, M. (2014). *Fisika untuk SMA/MA Kelas XI*. Jakarta: Penerbit Erlangga.
- Kanginan, M. (2014). *Fisika untuk SMA/MA Kelas XII*. Jakarta: Penerbit Erlangga.
- Karyono, Palupi, D. S., & Suharyanto. (2009). *Fisika untuk kelas X SMA dan MA*. Jakarta: Departemen Pendidikan Nasional.
- Klassen, S. (2006). The Science Thought Experiment: How Might it be Used Profitably in the Classroom? *Interchange*, 37(1-2), 77-96.
- Kösem, S. D., & Özdemir, Ö. F. (2014). The Nature and Role of Thought Experiments in Solving Conceptual Physics Problems. *Science & Education*, 23(4), 865-895.
- Lattery, M. J. (2001). Thought Experiments in Physics Education: A Simple and Practical Example. *Science & Education*, 10(5), 485-492.
- Levitt, K. E. (2002). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science education*, 86(1), 1-22.
- Mukaromah, A., & Suparwoto, S. (2016). Analisis BSE dan Non-BSE Fisika SMA Kelas X Kriteria Isi, Organisasi, Indeks serta Glosarium. *E-Journal*

- Pendidikan Fisika*, 5(7), 399-404.
- Myhreagen, H. V., & Bungum, B. (2016). 'From the cat's point of view': upper secondary physics students' reflections on Schrödinger's thought experiment. *Physics Education*, 51(5), 1-8.
- Niaz, M., Kwon, S., Kim, N., & Lee, G. (2013). Do general physics textbooks discuss scientists' ideas about atomic structure? A case in Korea. *Physics Education*, 48(1), 57-64.
- Nufus, N., & As, A. F. (2009). *Fisika SMA/MA Kelas X*. Jakarta: Departemen Pendidikan Nasional.
- Nurachmandani, S. (2009). *FISIKA 1 untuk SMA/MA Kelas X*. Jakarta: Departemen Pendidikan Nasional.
- Nurachmandani, S. (2009). *Fisika 2 untuk SMA/MA Kelas XI*. Jakarta: Departemen Pendidikan Nasional.
- Ogan-Bekiroglu, F. (2007). To What Degree Do the Currently Used Physics Textbooks Meet the Expectations? *Journal of Science Teacher Education*, 18(4), 599-628.
- Palupi, D. S., Suharyanto, & Karyono. (2009). *FISIKA untuk SMA dan MA Kelas XI*. Jakarta: Departemen Pendidikan Nasional.
- Pintrich, P. R. (2002). The Role of Metacognitive Knowledge in Learning, Teaching, and Assessing. *Theory Into Practice*, 41(4), 219-225.
- Purwanto, B. (2009). *Theory and Application of Physics 2*. Solo: Tiga Serangkai Pustaka Mandiri.
- Purwanto, B. (2009). *Theory and Application of Physics 3*. Solo: Tiga Serangkai Pustaka Mandiri.
- Reiner, M. (1998). Thought experiments and collaborative learning in physics. *International Journal of Science Education*, 20(9), 1043-1058.
- Reiner, M., & Burko, L. M. (2003). On the Limitations of Thought Experiments in Physics and the Consequences for Physics Education. *Science & Education*, 12(4), 365-385.
- Reiner, M., & Gilbert, J. K. (2004). The symbiotic roles of empirical experimentation and thought experimentation in the learning of physics. *International Journal of Science Education*, 26(15), 1819-1834.
- Saripudin, A., Rustiawan, K. A., & Suganda, A. (2009). *Praktis Belajar Fisika*. Jakarta: Departemen Pendidikan Nasional.
- Siswanto, & Sukaryadi. (2009). *Kompetensi Fisika Kelas XI*. Jakarta: Pusat Perbukuan, Departemen Pendidikan Nasional.
- Siswanto, & Sukaryadi. (2009). *Kompetensi Fisika Kelas XII*. Jakarta: Pusat Perbukuan, Departemen Pendidikan Nasional.
- Subagya, H. (2017). *Konsep dan Penerapan FISIKA SMA/MA Kelas XII*. Jakarta: PT Bumi Aksara.
- Suharyanto, Karyono, & Palupi, D. S. (2009). *FISIKA untuk SMA dan MA Kelas XII*. Jakarta: Pusat Perbukuan, Departemen Pendidikan Nasional.
- Sumarsono, J. (2009). *Fisika untuk SMA/MA Kelas X*. Jakarta: Pusat Perbukuan, Departemen Pendidikan Nasional.
- Sunardi, Retno, P. P., & Darmawan, A. B. (2016). *Fisika untuk Siswa SMA/MA Kelas X*. Bandung: Yrama Widya.
- Sunardi, Retno, P. P., & Darmawan, A. B. (2016). *Fisika untuk Siswa SMA/MA Kelas XII*. Bandung: Yrama Widya.
- Suparmo, & Widodo, T. (2009). *Panduan Pembelajaran Fisika untuk SMA & MA Kelas XII*. Jakarta: Pusat Perbukuan, Departemen Pendidikan Nasional.
- Velentzas, A., & Halkia, K. (2013). From Earth to Heaven: Using 'Newton's Cannon' Thought Experiment for Teaching Satellite Physics. *Science & Education*, 22(10), 2621-2640.
- Velentzas, A., & Halkia, K. (2013). The Use of Thought Experiments in Teaching Physics to Upper Secondary-Level Students: Two examples from the theory of relativity. *International Journal of Science Education*, 35(18), 3026-3049.
- Velentzas, A., Halkia, K., & Skordoulis, C. (2007). Thought Experiments in the Theory of Relativity and in Quantum Mechanics: Their Presence in Textbooks and in Popular Science Books. *Science & Education*, 16(3), 353-370.
- Watson, S. A. (2001). Learning Styles of Interior Design Students as Assessed by the Gregorc Style Delineator. *Journal of Interior Design*, 27(1), 12-19.
- Widodo, T. (2009). *FISIKA untuk SMA/MA*. Jakarta: Departemen Pendidikan Nasional.
- Widodo, T., & Suparmo. (2009). *Panduan Pembelajaran Fisika untuk SMA & MA Kelas X*. Jakarta: Departemen Pendidikan Nasional.
- Yulietta, R., & Sahidin, D. (2017). *FISIKA untuk SMA/MA Kelas X*. Jakarta: CV. Arya Duta.
- Yusrizal, Y., Suliyannah, S., & Basri, T. H. (2017). Analysis of Knowledge, Understanding and Skills of Physics Teachers of State Senior High Schools in Developing and Analyzing Test Items. *Jurnal Pendidikan IPA Indonesia*, 6(2), 335-340.



## THE IMPACT OF ENGINEERING DESIGN PROCESS IN TEACHING AND LEARNING TO ENHANCE STUDENTS' SCIENCE PROBLEM-SOLVING SKILLS

M. Syukri\*<sup>1</sup>, S. Soewarno<sup>2</sup>, L. Halim<sup>3</sup>, L.E. Mohtar<sup>4</sup>

<sup>1,2</sup>Syiah Kuala University, Banda Aceh, Indonesia

<sup>3,4</sup>Faculty of Education, Universiti Kebangsaan Malaysia, Bangi, Malaysia

DOI: 10.15294/jpii.v7i1.12297

Accepted: December 7<sup>th</sup>, 2017. Approved: February 21<sup>st</sup>, 2018. Published: March 19<sup>th</sup>, 2018

### ABSTRACT

This study aimed to determine the impact of the integration of engineering design process (asking, imagining, planning, creating and improving) in an electrical & magnetism module to improve problem-solving skills in physics among secondary school students in Aceh, Indonesia. The quasi-experimental study was carried out with 82 form three (age 15 years old) students of a secondary school in Aceh Besar, Indonesia. The first author had randomly chosen two classes as the experimental group and two other classes as the control group. Independent samples t-test analysis was conducted to determine the difference between the physics teaching and learning module which integrated the five steps of engineering design process and the existing commonly used science "Pudak" teaching and learning module. The results of the independent samples t-test analysis showed that the use of the physics teaching and learning module which integrated the five steps of engineering design process was more effective compared to the use of the existing "Pudak" module in increasing the students' skills in solving physics problems. The findings of the study suggest that the science learning approach is appropriate to be applied in the teaching and learning of science to enhance science problem-solving skills among secondary school students. In addition, it can be used as a guide for teachers on how to implement the integration of the five steps of engineering design process in science teaching and learning practices.

© 2018 Science Education Study Program FMIPA UNNES Semarang

**Keywords:** Physics teaching and learning module, engineering design, science problem solving, magnetic field

### INTRODUCTION

Science is an organized knowledge that is verifiable based on observations and experiments. It involves analyzing a phenomenon systematically and objectively for creating new knowledge that can be trusted (Johari et al., 2007; Maloney et al., 2001; Nikkhah, 2011). Science can also be interpreted as a way of thinking in solving a problem (Zurida et al., 2006). It involves the observation of an occurred phenomenon, predicting in a controlled manner what might happen, trying to

construct meaning from observation, and sharing knowledge with others. Problem-solving skills in science teaching and learning is an objective of science learning that is expected to be acquired by students so that they can apply scientific knowledge to the real world meaningfully (Kirkley, 2003; Lim, 2000).

In the Indonesian curriculum, science education is used as a comprehensive effort to uplift the lives of the people by improving their quality of life to create a society that has knowledge and problem-solving skills so that they can develop themselves as useful citizens (Evi, 2010; Widowati et al., 2017). Similarly, in various studies on scientific creativity, problem-solving skills were

\*Correspondence Address:  
E-mail: syukri.physics@unsyiah.ac.id



also used as an aspect of scientific creativity of students in science teaching and learning (Hu & Adey, 2002). Scientific creativity in teaching and learning of science is a skill to understand science concepts and to use them to solve problems in creative ways (Hu & Adey, 2002; Laius & Rannikmae, 2011).

Students are generally aware that science is a difficult subject when they are asked to solve problems. Although many students say that they understand the science concepts, they face difficulties when asked to solve problems in science (Lim, 2000). Problem-solving involves various metacognitive strategies to enable students to understand how they think and explore the various methods to solve problems in science (Halim et al., 2016; Lee 2007; Seth et al., 2007). For students to solve various problems in science effectively, appropriate teaching approaches are needed. Teachers should not only implement teaching that is limited to remembering formulas and skills to carry out mathematical operations. The teachers should teach the science concepts by emphasising the right steps and familiarising the students by checking their work and understanding of the concept through a constructivist and contextual approach to enable students to learn and solve science problems (Heson, 2004; Seth et al., 2007).

In the implementation of science teaching and learning, teachers still emphasise memorisation of facts rather than focusing on scientific methods or scientific inquiry (Sopiah et al. 2009). Teachers need to use teaching methods which are aided by media and laboratory activities (Husin et al., 2015; Sulistyanto & Rusilawati, 2009). Some teachers were found to perform practical work when teaching science; however, it is not based on a constructivist and contextual approach in which the emphasis is to improve students' metacognition to facilitate their skills in problem-solving which may not be well developed yet (Seth et al., 2007).

Contextual and constructivist teaching such as practical work and hands-on activities can enhance students' problem-solving skills. Accordingly, this can be implemented through the application of engineering design process in science teaching and learning (Cantrell et al. 2006; Henson, 2004; Schnittka, 2009). Teaching and learning of science based on engineering design process is an approach that can better train the process of thinking. By following learning activities based on engineering design, students will learn how to analyse the situation and gather the relevant information, define the problems, evalu-

ate and generate ideas creatively, develop ideas to solve problems effectively, as well as assess and make improvements to the solution. This is in line with the function and purpose of learning science itself, which is to develop scientific attitude through practical and scientific activities among students (Istikomah et al., 2016; Widowati et al., 2017).

Engineering design process has been reported by many studies to increase achievements in science teaching and learning, such as mastery of science concepts (Apedoe et al., 2008; Mehalik et al., 2008; Riskowski et al., 2009; Schnittka, 2009), interest and attitude towards science (Apedoe et al., 2008; Mehalik et al., 2008; Rogers & Portsmore, 2004), and to improve technical skills among students (Schnittka, 2009; Syukri et al., 2017). However, the skills of scientific problem-solving have not yet been reported in many studies. Thus, to demonstrate empirically how engineering design process can improve science problem-solving skills compared to existing teaching approaches, the researchers have integrated the steps of engineering design process into a science teaching and learning module. The impact of integrating the engineering design process in the module on students' science problem-solving skills was then compared to the existing "Pudak" science teaching and learning module.

Engineering design process as an approach to science teaching and learning in this study is a part of problem-based learning (Schnittka, 2009). Problem-based learning is an active learning strategy that is based on the theory of constructivism (Piaget, 1957; Vygotsky, 1978). The theory of constructivism and the engineering design process have the same goal, namely encouraging students to think and generate ideas or create innovative products based on existing knowledge and reasoning about everyday problems (Cunningham, 2007; Schittka, 2009). In this study, the theory of constructivism was used as the basis of integration of the five-steps engineering design process in the teaching and learning process in the classroom.

Problem-based learning and engineering design-based learning both begin with a science problem (Fortus et al., 2005; Schittka, 2009). The engineering design process approach is a problem-solving activity through the development of an idea or product that requires creative thinking in a systematic way, and assessment with the objective of arriving at the product itself (Eide et al., 2012; Haik, 2003; Hyman, 1998). Based on ABET (Accreditation Board for Engineering and Technology), engineering design processes

activities can be divided into nine activities, namely: (1) recognising the need; (2) defining the problem; (3) planning the project; (4) gathering information; (5) conceptualising alternative approaches; (6) evaluating the alternatives; (7) selecting the best alternatives; (8) communicating the design; and (9) implementing the preferred approach (Hyman, 1998). However, these nine activities in the ABET model can change according to the purpose and context to be studied. Usually, the researchers will focus on some activities only in line with the goals and objectives of the study (Haik, 2003; Hyman, 1998). Various studies involving integration of engineering design process in teaching and learning activities have taken the nine steps of activities in the ABET model and modified it to become a five-step learning activity, involving asking, imagining, planning, creating, and improving (Cunningham, 2007; Mehalik et al., 2008; MoS, 2012; Schittka, 2009; Wendell, 2011).

In line with the theoretical basis of this study, Becker and Park (2011) through a meta-analysis study involving various engineering design process studies conducted in teaching and learning found that generally, the integration leads to the implementation of teaching and learning characterised by constructivism. To implement the learning in each step of the engineering design process, students would still need guidance from the teacher on how they can carry out each step of the engineering design process effectively. Following the philosophy that learning is an active process, students construct their own meaning from the experience provided by the teacher. To ensure that students can build their own understanding through the five steps of engineering design process, teachers were asked to carry out the teaching process in phases according to the theory of constructivism by Needham, namely: orientation phase, phase of inducing ideas, phase of restructuring ideas, phase of ideas usage, and reflection phase (Needham, 1987).

Needham (1987) describes that in constructivist learning, teachers have different objectives that are to be achieved for each phase. The orientation phase aims to stimulate interest and provide a meaningful context for learning. The inducing idea phase is aimed at enlightening students about their initial ideas on the studied phenomenon. The phase of restructuring ideas aims to make students aware of the views of the phenomenon that they are studying, and students can extend, modify or replace their initial views. The phase of idea usage aims to use new situations to reinforce the ideas that students have

built. The phase of reflection aims to make students aware of changes in their initial ideas. The fifth phase is subsequently used as a guideline or approach in assisting teaching and ensuring that students apply each step of the learning activities according to the five-step engineering design process (ask, imagine, plan, create, & improve).

Teachers play different roles throughout the five phases of Needham's constructivism, and teachers need to provide help to ensure that students would be able to carry out the five steps of the engineering design process. In the asking step, teachers conduct the orientation phase, inducing the idea, and restructuring the idea. Teachers show students an everyday science phenomenon and direct them to make a connection with the science concepts that are being studied. The connection between new problems with students' existing knowledge will improve students' ability to synthesise the problem (Mehalik et al. 2008). In the imaging step, teachers go through the phase of restructuring the idea and provide active learning activities such as hands-on activities. Through existing and new knowledge of science concepts, students are directed to carry out some hands-on activities related to the previous asking step of the scientific phenomenon problem-solving. In order to solve the problem, students would certainly need skills based on knowledge and understanding of science concepts. In the planning step, teachers go through the phase of idea usage and direct students to the idea of designing a solution in the form of a graph that students imagined in the previous activity. In order to plan a solution according to the scientific concept, the student's knowledge and understanding of the science concept and problem must be strong. The plan produced in this activity can be applied in the form of a real science technical product design in the next creating step activity. In designing the product in the creating step, teachers also implement the idea usage phase which directs students to apply the science technical product design to the exact form of the plan they have designed. If the planned step was previously made only in the form of a graph or a diagram, then in the designing step activities, students run the application in the form of technical products to solve problems in science which are based on the science concept. In the improving step, teachers implement the reflection phase which directs students to assess the strengths and the weaknesses of the science technical products that have been produced. Although the evaluation is based on the various aspects of the activities such as form, function, and use, the main focus is on the

assessment of the product's technical aspect and compliance with the scientific concept of the study. After the technical products' weaknesses have all been identified, students are required to make improvements to the weaknesses. Every student activity in each step of the engineering design process is expected to result in problem-solving skills among students (Cantrell et al., 2006; Haik, 2003).

The order of the steps in the application of the five steps approach of engineering design process is not rigid. The processes of the engineering design activities are cyclical; it can begin at any step and move forward or backward. However, to enable students to apply the five steps, such activities are carried out in sequence starting from the asking step; this is so that However, to enable students to apply the five steps, such activities are carried out in sequence starting from the ask step. This would enable the students to easily understand the steps and follow the steps according to the engineering design process model (Cunningham, 2007; MoS, 2012). From the descriptions of each step of the above activities and the findings of various studies, the integrated engineering design approach could be implemented in the teaching and learning of science. It can be concluded that the selection of engineering design process as an approach to the science teaching and learning module is appropriate.

In line with the purpose of the study, students are expected to acquire the science skills after they have implemented the five steps of the engineering design process. The science problem skills in this study are the dependent variable used to determine the impact of the science teaching and learning module that was built based on the five steps of engineering design process and was taught using Needham's five phases of constructivism. Science problem-solving skills refer to the ability of students to solve problems based on science concepts that are learned. In general, problem-solving is a thinking skill that combines critical and creative thinking skills to get the information and ideas to solve science problems using a creative and scientific method. Therefore, this study, through a quasi-experimental method, was aimed at determining whether there are any significant differences in students' science problem-solving skills among students who used the treatment module and those who used the existing "Pudak" module.

## METHODS

The effectiveness of the teaching and learning module of this study in relation to the existing teaching and learning module on students' science problem-solving skills was compared through a quasi-experimental design. The study was carried out in one junior high school in Aceh Besar. The school was selected from 47 schools which conduct science activities through purposive sampling method. In this selected school, two classes were randomly selected (simple random sampling) as the experimental group and two other classes as the control group. The experimental group practiced the electric & magnet module which was on electricity and magnetism, while the control group used the existing science teaching and learning module that are commonly utilised in Aceh on the same two topics.

The science teaching and learning module used in this study integrated the five steps of engineering design process. The five steps of engineering design process are the modified version of the nine steps of engineering design activities (Hyman 1998) that have been adopted in various studies in science education (Cunningham, 2007; Mehalik et al., 2008; MoS, 2012; Schittka, 2009; Wendell, 2011). The five steps of the engineering design activities are asking, imagining, planning, creating, and improving.

Before the students embarked on the first step which is asking, they were given a scenario about a student who wanted to make a science technical product that could generate electricity from a fan. In the process of designing the product, the student in the scenario needed help to make the science technical product that could produce electrical energy based on the concepts of electricity and magnetism. Briefly, in each step of the engineering design, the students in the experimental group had to carry out the learning activities as follows: (1) in the ask step, the students explored the problem and figured out how to create a product that does not use electricity or "free electricity energy" based on the knowledge of science concepts they had learned; (2) in the imagining step, the students had to think and imagine the science technical product to solve the science problem of "free electricity energy". Three hands-on activities on the science concepts were prepared for the students to assist them in thinking and imagining the possible solutions in creating the science technical product; (3) in

the planning step, the students designed possible solutions in the form of diagrammatic solutions which they had imagined in the previous activity; (4) in the creating step, the students developed the science technical products to the exact form of the plan which they had created for solving the science problem of "free electrical energy"; and (5) in the improving step, the students made improvements to the science technical products which they had developed based on the weaknesses and shortcomings that were identified by the teachers and students in the other groups. Finally, after going through the steps, the students would be able to produce a science technical product that could change the rotation of the fan into electrical energy based on the scientific concepts of electrical & magnetic fields. Each step in the engineering design process which was integrated with the electric and magnetism module was validated by three experts; an expert in physics concepts, an expert in teaching and learning module development, and an expert in engineering design process. Changes were made accordingly based on the recommendations made by the experts.

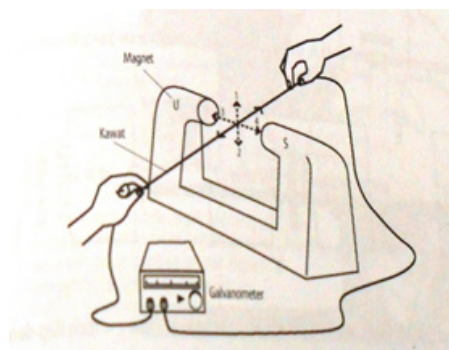
The existing science teaching and learning module that is commonly used in Aceh is "Pudak". This module is a module of science teaching and learning that combines the information in the science textbooks with laboratory activities. The "Pudak" module is used in the process of teaching and learning either simultaneously or after students have been taught the theories and concepts from the science textbooks. The "Pudak" module derived its name from the name of the publisher or company that published the lab activity module. Generally, the "Pudak" module begins with the teaching of the science concept from the science textbook. After that, the students are directed to carry out the laboratory activities by following the steps provided in the module. Generally, the activities in the module are divided into three activities, namely, the explanation of the purpose and objectives, description of equipment/ materials, instruction on the steps of designing, and conclusions about the observations of the results.

The procedure of this quasi-experimental study i.e. to compare the teaching and learning of the science module was divided into four phases, namely: Phase 1: making a preliminary study and making plans for the construction of the module and the instrument; Phase 2: building the research module and instruments; Phase 3: determining the validity of the research modu-

le, conducting the pilot study, and improving the module and the instrument; Phase 4: conducting information dissemination and training sessions for the teachers to implement the module and carry out the actual study; Phase 5: carrying out the evaluation of the effectiveness of the module used by the quasi-experimental group and the control group.

To determine the effectiveness of both module in improving problem-solving skills in science, the first author used ten science problems in the form of objective questions related to the topic of electricity and magnetism. Each question tested the students' understanding and skills about the concepts of electricity and magnetism and application of these concepts to solve science problems in students' everyday lives. The ten science questions were formulated by adapting the problems of electrical & magnetic fields from various science textbooks into science problems in the students' everyday lives. One of the given science problems is as follows:

*"During physics learning in school, Fatin and Fatan had been taught about the concept of electromagnetic induction. The teacher taught that the changes of magnetic force lines will be able to produce electric current. To prove the concept, Fatin and Fatan connected two magnets, electrical wires and a galvanometer, as shown in Figure 1".*



**Figure 1.** Connection of Two Magnets, Electrical Wires and a Galvanometer

However, Fatin and Fatan were still worried that their hand movements would induce an emf (electric current). According to your knowledge, the direction of the right hand to produce induction (electric current) is..."

To determine the validity and reliability of the instrument, the first author gave the instrument to two experts and also carried out a pilot study with 38 students. The results of the pilot study analysis by using the Kuder-Richardson 20 (K-R 20) formula showed that the reliability (r)

was 0.73. The value of  $r$  showed that the science questions were acceptable and reliable (Ridwan, 2010).

The inferential statistical analysis of independent samples t-test was conducted before and after treatment to determine the effectiveness of the teaching and learning module on the science problem skills of the students in the experimental group and the control group. An independent samples t-test before treatment was conducted to determine whether the level of skills among the students in the quasi-experimental group and the control group were equivalent. An independent samples t-test was conducted after the treatment to determine the level of science problem-solving skills between the groups of students using the study's teaching and learning module and students who used the existing module. The before

and after treatment independent samples t-test was also used to test the two null hypotheses ( $H_0$ ) in this study:  $H_{01}$ : There are no significant differences in science problem skill level between the quasi-experimental group and the control group in the pre-test; and  $H_{02}$ : There are no significant differences in science problem-solving skills level between the quasi-experimental group and the control group in the post-test.

## RESULTS AND DISCUSSION

A total of 82 students were involved in this study, of which 40 were in the experimental group and the other 42 in the control group. The profiles of students involved in the quasi-experimental group and the control group are shown in table 1.

**Table 1.** Student Profiles Based on Groups

Background	Experimental group	Control group
No. of students	40 students Class IXB : 22 Class IXD: 18	42 students Class IXA : 20 Class IXC : 22
Gender	24 males Class IXB : 12 Class IXD : 12 16 females Class IXB : 10 Class IXD : 6	22 males Class IXA : 10 Class IXC : 12 20 females Class IXA : 10 Class IXC : 10
Form	Three	Three
Teaching and learning	Using science teaching and learning module based on engineering design.	Using the commonly used "Pudak" module.

To identify the level of science problem solving skills in both groups of students and also to meet the assumption that students of both groups were equivalent, all students were asked to solve ten multiple-choice context-based science

questions. The results of the descriptive analysis of the mean score, the students' responses, and the level of science problem solving skills of both groups are shown in table 2.

**Table 2.** Mean Score, Standard Deviation, and the Level of Science Problem Solving Skills for both Groups before the Treatment

Variable	Experimental group N = 40			Control group N = 42		
	M	S.D	Level	M	S.D	level
Science problem solving skills	3.00	1.41	26 (62%) Low  14(35%)Me- dium	3.02	1.55	27(64%) Low  15(35.7%)Me- dium

Analysis of the independent samples t-test to identify the differences in the mean score of students' answers and level of science problem solving skills before the treatment for both groups are shown in table 3.

**Table 3.** Results of the Independent Samples T-test Analysis of Students' Science Problem Solving Skills' Pre-test Score for the Experimental Group and the Control Group

Variable	Group	No.	Mean	S.D	t-value	df	Sig.
Science problem solving skills	Experimental	40	3.00	1.41	- 0.072	80	0.942
	Control	42	3.02	1.55			

\* Significance level  $p = 0.05$

Based on table 3, the results of the independent samples t-test analysis showed that there was no significant difference in the mean score of science problem solving skills before the treatment was conducted among the students in the experimental group (mean = 3.00) and the students in the control group (mean = 3.02) with  $t(80) = -0.072$ ,  $p = 0.942$  ( $p > 0.05$ ). These findings demonstrate that before the treatment was con-

ducted, both groups of students had equivalent level of scientific problem solving skills.

After both groups were taught using the two module for twelve weeks, they were asked to answer the same problem solving questions again. The mean score of students' responses and level of science problem solving skills for the experimental group and the control group after treatment are shown in table 4.

**Table 4.** The Mean Scores, Standard Deviations, and Level of Science Problem Solving Skills for both Groups after Treatment

Variable	Experimental group N = 40			Control group N = 42		
	M	S.D	Level	M	S.D	level
Science problem solving skills	5.53	1.81	5(12.5%) Low	4.23	1.80	18 (42.9%) Low
			32(80%) Medium			23 (54.8%) Medium
			3(7.3%) Excellent			1 (2.4%) Excellent

Analysis of the independent samples t-test to identify differences in the mean score of students' answers and level of science problem

solving skills after treatment in both groups are shown in table 5.

**Table 5.** Results of the Independent Samples T-test Analysis of Students' Science Problem Solving Skills' Post-test Score for the Experimental Group and the Control Group

Variable	Group	No.	M	S.D	t-value	df	Sig.
Science problem solving skills	Experiment	40	5.35	1.81	2.777	80	*0.007
	Control	42	4.23	1.80			

\* Significance level  $p = 0.05$

The results of the independent samples t-test analysis after treatment (Table 5) showed that there was a significant difference in the mean score of science problem solving skills between the students in the experimental group (mean = 5.35)

and the students in the control group (mean = 4.23) with  $t(80) = 2,777$ ,  $p = 0.007$  ( $p < 0.05$ ). The mean score of students in the experimental group was higher compared to the students in the control group. This shows that the science problem

solving skills of the students in the experimental group which used the teaching and learning module that integrated the five steps of engineering design during science instruction was higher compared to that of the control group which used the "Pudak" module. In other words, it can be concluded that the integration of the five steps of engineering design process in the teaching and learning of science has managed to improve the science problem solving skills of the students.

Integrating the five steps of engineering design process (asking, imagining, planning, creating, and improving) in the science teaching and learning module on the topic of electrical & magnetic fields appears to have increased the students' proficiency in science problem solving skills. The positive increase in the students' problem solving skills is the result/outcome of the integration of the five steps of engineering design process, namely asking, imagining, planning, creating, and improving which were prepared systematically in this electrical & magnetic module.

The asking step that presents the contextual narrative or story of problems in science, in this case "free electricity", gives an overview of the educational activities to the students in terms of the goals and objectives of the learning itself (Hyman, 1998; Rockland et al., 2010). The science problem on "free electricity" was given to the students in the form of a science story describing the happenings of students' real life everyday experiences to enable them to understand the scientific issues well and deeply. Through good understanding of the problems, students will understand the science concepts more easily such that they will be able to explain and resolve the problems (Apedoe et al., 2008; Fortus et al., 2005; Syukri et al., 2012). Thus, it is not surprising if the "free electricity" science problem and the concept of electrical & magnetic fields which was developed in the asking step of the activity managed to improve the students' skills and knowledge of science

Next, the imagining step in this science teaching and learning module also contributed to students' problem solving skills in science. In this step, the students were given instructions by the teachers to implement the application of concepts of electricity and magnetism through three hands-on activities. According to Rockland et al. (2010), the use of practical approaches such as the application of science concepts through hands-on activities in the engineering design process will help students to find relationships between concepts they learn with technology and problems in their daily lives. The ability of students to find

relationships between scientific concepts and real life will allow them to apply science concepts to solve problems in their everyday lives (Apedoe et al., 2008; Syukri et al., 2012).

After carrying out the three hands-on activities in the imagining step, the students were then asked in the planning and creating steps to apply the concepts of electricity and magnetism to come up with a science technical product to solve the problem of "free electricity energy" as described in the asking step. Through understanding of the concept of electrical & magnetic fields that they have learned, students in these two steps are required to solve the problem of science "free electricity" in the form of a science technical product. The ability to apply the understanding of science concepts in everyday life such as planning and designing a science technical product to solve a problem may help improve the students' skills in understanding and solving science problems (Apedoe et al., 2008; Fortus et al., 2005).

The effectiveness of the five steps of engineering design process in the science teaching and learning module on students' skills development in solving science problems depended on the sequence of steps of learning planned by the first author. It began with a context-based science problem and ended with the technical product to solve the problem, and these steps encouraged the students to show their ability to solve problems. This finding is consistent with the views of the science teachers who implemented the science teaching and learning by using the scientific creativity module developed for this study, as exemplified by the statement made by one of the teachers: *"Even before I actually performed an active learning activity involving engineering design, I did not manage the learning flow step by step like in this module. I rarely did the ask step, but this is important to stimulate students to think on how to solve the given problem so that they can create a product to solve the problem"*.

The asking and designing steps are two activities which provided more stimuli to students' problem solving skills. In the asking step, the students learned about the science concept and connected it to the "free electricity energy" context-based science problem. Through the three hands-on activities in the imagining step the students attempted to think of how the implementation of the application of the science concepts can be used in a science technical product to solve the problem of "free electricity". This finding corresponds with one of the statements made by a student: *"The ask step in this module was good because we were given a good scientific problem in*

a real-life situation so it made it easy for us to imagine. In addition, the concepts of electricity and magnetism that taught us to solve problems in science through such concepts. The imagining step in this module included hands-on activities that are helpful in imagining about what we should do to solve the science problem of "free electricity energy".

The honest and positive views of the teachers and students on the five steps engineering design process also reinforced the effectiveness of engineering design process in teaching science. The numerous positive effects of the integration of the engineering design process in the teaching and learning of science can lead to better and increased science problem solving skills among students. Thus, it should be integrated in the science curriculum to improve students' achievements and skills, especially in science problem solving skills.

### CONCLUSION

The well-planned and systematic development of the module which was based on an appropriate teaching model gave very positive impact on various achievements and skills among the students. This study integrated the five steps of engineering design process as an approach in students' learning of science to improve students' science problem solving skills. Using independent samples t-test analysis, the results showed that there were significant differences between the science problem solving skills of the students in the experimental group compared to those in the control group. It was found that the mean scores of science problem solving skills in the experimental group that used the science teaching and learning module based on the five steps of engineering design process were higher than the mean score of the control group that used the existing "Pudak" module. The findings of this study led to the conclusion that the five steps of engineering design process implemented in the science teaching and learning module which included the steps of asking, imagining, planning, creating, and improving could improve students' science problem solving skills as reported by various previous studies.

### REFERENCES

- Apedoe, X. S., Reynolds, B., Ellefson, M. R. & Schum, C. D. (2008). Bringing engineering design into high school science classrooms: The heating/cooling unit. *Journal of Science Education and Technology*, 17(5), 454-465.
- Becker, K., & Park, K. (2011). Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM Education: Innovations and Research*, 12(5/6), 23.
- Cunningham, C. M., & Hester, K. (2007). Engineering is elementary: An engineering and technology curriculum for children. In *American Society for Engineering Education Annual Conference & Exposition, Honolulu, HI*.
- Eide, A. R., Jenison, R.D., Northup, L.L. & Mickelson, S. K. (2012). *Engineering Fundamental and Problem Solving*. New York: McGraw-Hill.
- Evi, S. (2010). *Kesan pengajaran dan pembelajaran kontekstual ke atas kemahiran proses sains, penyelesaian masalah, sikap saintifik dan pencapaian dalam matapelajaran biologi*. Thesis Doctor of Philosophy: Universiti Kebangsaan Malaysia.
- Fortus, D., Krajcik, J., Dershimer, R. C., Marx, R. W. & Mamlok-Naamand, R. (2005). Design-based science and real-world problem solving. *International Journal of Science Education*, 27(7), 885-879.
- Haik, Y. (2003). *Engineering Design Process*. CA, USA: Pacific Grove.
- Halim, A., Yusrizal, Y., Susanna, S., & Tarmizi, T. (2016). An analysis of students' skill in applying the problem solving strategy to the physics problem settlement in facing AEC as global competition. *Jurnal Pendidikan IPA Indonesia*, 5(1), 1-5.
- Henson, K. T. (2004). *constructivist methods for teaching in middle-level classrooms*. Boston: Allyn and Bacon.
- Hu, W., & Adey, P. (2002). A scientific creativity test for secondary school students. *International Journal of Science Education*, 24(4), 389-403.
- Hyman, B. (1998). *Fundamentals of Engineering Design*. New Jersey: Prentice-Hall.
- Istikomah, H., Hendratto, S., & Bambang, S. (2016). Penggunaan Model Pembelajaran Group Investigation untuk menumbuhkan sikap ilmiah siswa. *Jurnal Pendidikan Fisika Indonesia*, 6(1), 40-43.
- Kirkley, J. (2003). Principles of teaching problem solving: technical paper 4.
- Laius, A. & Rannikmae, M. (2011). Impact on student change in scientific creativity and socio-scientific reasoning skills from teacher collaboration and gains from professional in-service. *Journal of Baltic Science Education*, 10(2), 127-137.
- Lee, M. K., & Erdogan, I. (2007). The effect of science-technology-society teaching on students' attitudes toward science and certain aspects of creativity. *International Journal of Science Education*, 29(11), 1315-1327.
- Lim, Y. K. (Ed.). (2000). *Problems and solutions on atomic, nuclear and particle physics*. World Scientific Publishing Company.
- Hieggelke, C., Maloney, D., Van Heuvelen, A., & O'Kuma, T. (2001). Surveying students' con-



- ceptual knowledge of electricity and magnetism. *American Journal of Physics*, 69(7), S12-S23.
- Mehalik, M. M., Doppelt, Y., & Schunn, C. D. (2008). Middle-school science through design-based learning versus scripted inquiry: Better overall science concept learning and equity gap reduction. *Journal of Engineering Education*, 97(1), 71-85.
- Museum of Science [MoS]. (2012). *EiE: engineering & technology lessons for children!* Retrieved from <http://www.mos.org/eie/>.
- Needham, R., & Hill, P. (1987). Teaching Strategies for Developing Understanding in Science. Children's Learning in Science Project.
- Nikkhah, A. (2011). Science education of the new millennium: mentorship arts for creative lives. *Creative Education*, 2(4), 341.
- Piaget, J. (1957). *Construction of Reality in the Child*. London: Routledge.
- Efendi, R. (2010). Kemampuan Fisika Siswa Indonesia dalam TIMSS (Trend of International on Mathematics and Science Study). In *Prosiding Seminar Nasional Fisika* (pp. 384-393).
- Riskowski, J. L., Todd, C. D., Wee, B., Dark, M., & Harbor, J. (2009). Exploring the effectiveness of an interdisciplinary water resources engineering module in an eighth grade science course. *International journal of engineering education*, 25(1), 181.
- Rockland, R., Bloom, D. S., Carpinelli, J., Burr-Alexander, L., Hirsch, L. S., & Kimmel, H. (2010). Advancing the "E" in K-12 STEM education.
- Rogers, C. & Portsmore, M. (2004). Bringing engineering to elementary school. *Journal of STEM Education*, 5(3&4), 17-28.
- Schnittka, C. G. (2009). *Engineering design activities and conceptual change in middle school science*. Dissertation: University of Virginia.
- bin Sulaiman, P. D. S., binti Abdullah, F. A. P., & binti Ali, M. (2007). Kemahiran Metakognitif Dalam Kalangan Pelajar Sekolah Menengah di Negeri Johor Dalam Menyelesaikan Masalah Fizik.
- Sopiah, S. (2009). Pembiasaan Bekerja Ilmiah Pada Pembelajaran Sains Fisika Untuk Siswa Smp. *Jurnal Pendidikan Fisika Indonesia*, 5(1), 80-92.
- Sulistiyanto & Rusilowati, A. (2009). Pengembangan kreativitas siswa dalam membuat karya ipa melalui model pembelajaran problem based-instruction di SMP. *Jurnal Pendidikan Fisika Indonesia*, 5(2), 102-107.
- Syukri, M., Halim, L., & Meerah, T. S. M. (2012). Model Pendekatan Pakar Fisika Dalam Menyelesaikan Masalah Fisika Kontekstual: Sebuah Studi Kasus. *Jurnal Pendidikan Fisika Indonesia*, 8(1), 61-67.
- Syukri, M., Halim, L., & Mohtar, L.E. (2017). Engineering design process: cultivating creativity through science technical product. *Jurnal Fizik Malaysia* 38(1), 10055-10065.
- Vygotsky, L. S. (1978). *Mind in Society*. Cambridge: Harvard University Press.
- WAN, W. N. F., Fairuz, M., Syukri, M., & Halim, L. (2015). Competencies of science centre facilitators. *Journal of Turkish Science Education*, 12(2), 49-62.
- Wendell, K. B. (2011). *Science through engineering in elementary school: Comparing three enactments of an engineering-design-based curriculum on the science of sound*. Tufts University.
- Widowati, A., Nurohman, S., & Anjarsari, P. (2017). Developing Science Learning Material with Authentic Inquiry Learning Approach to Improve Problem Solving and Scientific Attitude. *Jurnal Pendidikan IPA Indonesia*, 6(1), 32-40.



## CONTROL PEST OF LEAF CATERPILLARS (*Plutella xylostella*) IN DELIMA ROSE APPLES USING SOURSOP LEAF EXTRACT (*Annona muricata*)

A. V. Amalia\*<sup>1</sup> and M. H. Yusa<sup>2</sup>

<sup>1</sup>Department of Integrated Science, FMIPA, State University of Semarang

<sup>2</sup>Technische Universität Berlin, Germany

DOI: 10.15294/jpii.v7i1.12484

Accepted: December 27<sup>th</sup>, 2017. Approved: February 15<sup>th</sup>, 2018. Published: March 19<sup>th</sup>, 2018

### ABSTRACT

The increasing of pesticide use is in line with the increasing number of pest populations. However, the use of pesticides causes various negative impacts on the environment (soil, water, and air) such as pesticide-resistant pests, perishing of useful insects which are non-target pesticides, and the use of pesticide which can even lead to poisoning and death in humans. One of the environmentally-safe techniques to control pests is chemical, by the use soursop leaf extract. This study aims to determine the most effective concentration of soursop leaf extract (*Annona muricata*) in controlling leaf caterpillar (*Plutella xylostella*) in delima rose apples. The research was carried out in the plantation area of rose apples in tempuran village, Demak. The research method employed experimental research. The study was conducted using Completely Randomized Design. The data were obtained using probit analysis of LC<sub>50</sub>. The most effective concentration of soursop extract (*Annona muricata*) on leaf caterpillars' mortality was 75 ppm. Soursop leaf extract (*Annona muricata*) has been proven to influence rose apples leaf caterpillars' mortality index. The LC<sub>50</sub> value of soursop leaf extract was 75,16 mg/L. The result showed that soursop leaf extract (*Annona muricata*) is effective as a biopesticide material to control leaf caterpillar pest for delima rose apples.

© 2018 Science Education Study Program FMIPA UNNES Semarang

**Keywords:** soursoap leaf extract, leaf caterpillar, delima apple rose

### INTRODUCTION

The cultivation of rose apple plants was commonly developed by the people of Demak. Rose apple is one of the potential local fruit commodities. Rose apples that grow in Southeast Asia comes from the Java island and is known as 'Javanese Apple' (Morton, 1987, Zen-hong, et al. 2007) which is quite special because it has a big fruit shape and sweet taste (Morton, 1987; Hariyanto, 1991). The varieties of rose apple grown

in Demak are delima and citra. Those varieties have been recognized nationally as the special and superior rose apples from Demak regency. Its attractive pink color, which indicates sweetness, as well as its own delicious aroma with a gentle tenderness of delima rose apples that always makes people addicted to eating it continuously. Delima rose apples are not as big as citra rose apples, but delima rose apple is more delicate, has a more distinctive aroma, and always causes a soft sensation when biting

However, due to the lack of serious handling from local government and fruit farmers, the products of delima rose apples experience a

\*Correspondence Address

E-mail: andinvita@mail.unnes.ac.id

decreasing trend from year to year. The decline in the production of delima rose apples is likely due to the size of land, the amount of fertilizer, pests and working days. One of the most common causes of crop failure is pest attack. The main pests in the cultivation of rose apple plants are leaf roller (*Apoderus sp.*), leaf borer (*Acrocercopseugeniel-la*), white lice (*Pseudococcus citrilus Cox*) and fruit fly (*Bractocera albistrigata*). Leaf caterpillar attacks the rose apple plants and it often decreases crop productivity. One of the preventions of pests is by using chemicals or synthetic pesticides. Pest control currently used by farmers still prioritizes chemical control with synthetic chemical pesticides both in dry and paddy fields periodically between 7 to 15 days depending on the condition of the attack. Initially, synthesis pesticides are considered to have several advantages. The use of synthetic pesticides has a negative impact on the environment even for its own users. Excessive use of chemical pesticides has a negative impact on the environment and people (Salaki et al., 2012; Li & Zhihui, 2008; Mamun & Ahmed, 2013).

Some of the negative impacts of pesticide use include pesticide-resistant pests, higher maintenance costs due to high prices of pesticides and excessive use which results in toxic to the environment, humans, and livestock (Khairil, 2017; Zarin et al, 2009; Bardin et al, 2008; Araar et al., 2009). One alternative in the prevention of pests that is safe for the environment and human can be done with biological control technique called biopesticide. The biopesticide is an integrated component of pest and disease control. In Indonesia, biopesticides are still less popular, the knowledge of biopesticides is equated with organic farming, whereas technology is widely available (Sumartini, 2017). Biopesticide by using soursop leaf extract (*Annona muricata*) is expected to eradicate pests in a safe and environmentally friendly way (Prado et al, 2014; Ribeiro et al, 2014). The content of plant compounds can show various kinds of biological activity in insects such as inhibition/rejection of food, spanking rejection activity, growth and development inhibitory activity, and death effect. Therefore, these biopesticides can be used to control plant pest organism (Hasnah, 2009).

The application of extracts to inhibit the growth of pests has also been done in previous research such as garlic plant extracts to cope with snail pests (Rusdy, 2010); papaya leaf extract to

inhibit plant pests (Setyawati & Julaily., 2013), inhibit larvae of *Plutella xylostella* (Siahaya & Rumthe, 2014; Yuliani & Kuswanti, 2013); ethanol extract of melinjo leaves (Moniharapon & Moniharapon, 2014); dan jengkol rind extract (Ambarningrum et al., 2011).

The toxic properties of plant compounds on insects may be in the form of antifeedants, repellent, cause death, inhibit spawning, interfere with development and reproduction (Princess, 2014). Active chemical compounds in the form of acetogenin contained in the leaves and seeds of soursop can be used to control the trips attack, suppress the intensity of the attack of green ladybugs and reduce the population. Acetogenin is also insecticidal (anti-insect-worm) and anti-feeding or lowering appetite (Maryani, 1995). Therefore, it is necessary to investigate the effectiveness of bioactive compounds from soursop leaf extract whether or not it is able to inhibit the development of caterpillar leaves on delima rose apples.

## METHODS

This research was conducted in the biology laboratory of FMIPA UNNES and the plantation area of delima rose apple plants in Demak. The selected approach to achieve the research objectives was through experimental studies. This experimental study used an independent variable of dead leaf caterpillar (*Apoderus sp.*), and a dependent variable of soursop leaf extract with various concentrations. The data were obtained by determining the value of  $LC_{50}$  through Probit analysis technique to know if there is a mortality difference of each treatment and find out low, efficient and environmentally friendly soursop leaf concentration.

## RESULTS AND DISCUSSION

Mortality is a major change observed in the toxicity test. Animal mortality data were required to determine the  $LD_{50}$  value. Observation on leaf caterpillar mortality was done in 24 hours with an interval of 8 hours. Test of leaf caterpillar mortality was performed on 5 treatment groups with 5 replications. Each treatment was given 100 leaf caterpillars. The dead leaf caterpillars were calculated to find out the average of leaf caterpillar mortality index (table 1).

**Table 1.** Average of Leaf Caterpillar Mortality Index

Treatment	Concentration Log	Repetition	Total of Caterpillar	Result of Caterpillar Mortality	Average of Caterpillar Mortality Index
P0	0	1	20	4	2,6
		2	20	1	
		3	20	3	
		4	20	3	
		5	20	2	
P1	1,40	1	20	10	13,2
		2	20	13	
		3	20	15	
		4	20	15	
		5	20	13	
P2	1,70	1	20	16	16,4
		2	20	17	
		3	20	16	
		4	20	17	
		5	20	16	
P3	1,88	1	20	17	18,6
		2	20	19	
		3	20	19	
		4	20	20	
		5	20	18	
P4	2,00	1	20	20	19,4
		2	20	20	
		3	20	19	
		4	20	20	
		5	20	18	

Information:

P0 = Negative Control (without treatment)

P1 = Soursop Leaf Extract of 25 ppm Concentration

P2 = Soursop Leaf Extract of 50 ppm Concentration

P3 = Soursop Leaf Extract of 75 ppm Concentration

P4 = Soursop Leaf Extract of 100 ppm Concentration

Based on table 1, it can be seen that caterpillar mortality is increasing as the concentration increases. The highest mortality at P4 treatment was followed by P3, P2, P1 and P0 treatment. At P1 treatment (soursop leaf extract of 25 ppm concentration), the average leaf caterpillar mortality index reached 13.2. At P2 treatment (soursop leaf extract of 50 ppm concentration), the average of caterpillar mortality index was 16.4. At P3 treatment (soursop leaf extract of 75 ppm concentration), the average of caterpillar mortality index was 18.6. While at P4 treatment (soursop leaf extract of 100 ppm concentration), the average of caterpillar mortality index was 19.4. This means that the higher concentration of

soursop leaf extract, the higher the rate of pest's death. This is due to the fact that soursop leaf extract contains *annonaceous acetogenin* compounds that could cause various effects on the growth and development of insects, among others: (1) inhibiting the development of egg, larva or pupa; (2) blocking the skin-changing process during the larval stage; (3) disrupting to the mating process; (4) eating rejection in larvae and adults; (5) preventing laying eggs; (6) making barren insects; (7) poisoning larvae and mature insects. The utilization of soursop is effective, seen from the fact that the higher the dose of soursop leaf extract is used, the higher the rate of caterpillars' death. According to the average of leaf caterpillar mor-

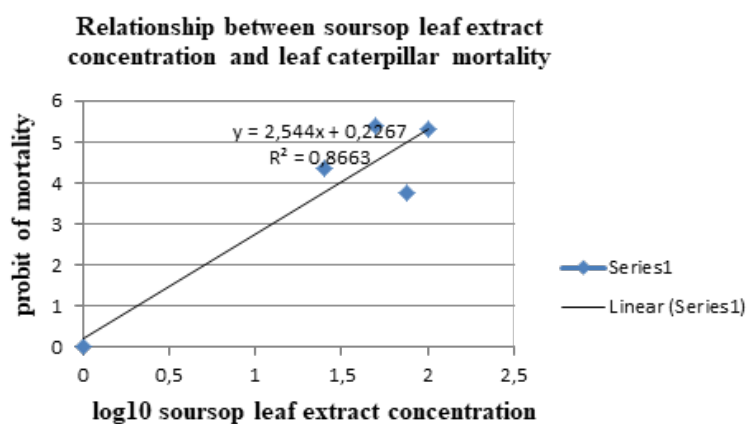
tality index presented above, then the probit analysis could be done as a follow-up. Probit analysis result of soursop leaf extract on leaf caterpillar can be seen in table 2.

**Table 2.** Probit Analysis Result

Treatment	% Mortality	% Corrected Mortality	Average of Corrected Mortality	Probit Value
P0	20	0	0	0
	5	0		
	15	0		
	15	0		
	10	0		
P1	50	31,25	6,25	4,36
	65	60,61		
	75	61,86		
	75	61,86		
	65	56,12		
P2	80	33,33	6,67	5,41
	85	22,99		
	80	5,88		
	85	11,76		
	80	17,24		
P3	85	5,95	1,19	3,77
	95	12,05		
	95	17,86		
	100	18,07		
	90	11,90		
P4	100	18,07	3,61	5,33
	100	6,17		
	95	0,00		
	100	0,00		
	90	0,00		

The above table shows that the higher the concentration given to the leaf caterpillar, the higher the probit value. The probit value of each treatment can be used to determine the relation-

ship between the caterpillar probit mortality and concentration log of soursop leaf extract as seen in figure 1.



**Figure 1.** Relationship between Caterpillars' Probit Mortality and Concentration Log of Soursop Leaf Extract

The linear regression equation of  $Y = 2.544 X + 0.226$  from figure 1 was employed to find the value of  $LC_{50}$ . The value of Y shows the probit value of death (mortality) of the caterpillar and X is the concentration log of soursop leaf extract. The results of the research obtained in table 2 then were tested statistically by ANOVA (Ana-

lysis of Variance) test which then continued with further Duncan test. The ANOVA test was used to find out the mean difference between two variation sources, namely the treatment group and the leaf caterpillar mortality group. The results of ANOVA test are as follows:

**Table 3.** Summary of ANOVA Result on Leaf Caterpillar Mortality

Variation source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	933.360	4	233.340	147.684	.000
Within Groups	31.600	20	1.580		
Total	964.960	24			

Information:

F Count <F 5% = Not significantly different (TN)

F 5% <F Count <F 1% = Real Different (\*)

F Count > F 1% = Very Real Different (\*\*)

The value of F Count was 147,684, bigger than  $F_{table}$  of 5% (2,87). Thus, it can be concluded that there was a very real difference between the treatments. After the ANOVA test was done, further Duncan test was carried out to compare the treatments. Since the dose groups had signi-

ficant differences, these groups were tested using Duncan test. In addition, Duncan test aimed to know difference test of each treatment. To find out the treatments having the same effect, please see table 4 below.

**Table 4.** Leaf Caterpillar Mortality Result from Duncan test

Concentration	N	Subset for alpha = 0.05			
		1	2	3	4
0	5	2.6000			
25	5		13.2000		
50	5			16.4000	
75	5				18.6000
100	5				19.4000
Sig.		1.000	1.000	1.000	.326

Means for groups in homogeneous subsets are displayed.

According to table 4, it can be seen that P0, P1, P2, P3, and P4 treatment have significant differences among the treatment groups. This shows that there was an influence of soursop leaf extract (*Annona muricata*) to leaf caterpillar mortality index of delima rose apples.

The application of agricultural systems by combining the technology of biopesticide and biological fertilizers has the prospect of increasing land supporting capacity, optimizing the use of fertilizers and suppressing soil infectious diseases (Prabowo, 2008). The effect of soursop leaf

extract has also been tested to overcome *Spodopteralitura* pests with low concentration (8%). The effectiveness test of soursop leaf extract (*Annona muricata*) on the mortality of leaf caterpillars in rose apples plants studied in this study was an initial effort to obtain environmentally friendly biopesticide to manage pathogenic disease in the field. Soursop leaf extract (*Annona muricata*) is known to have anti-insect properties and have toxicity. An examination of soursop leaf extract as biopesticide to mortality of peach leaf lice in chili plants has also been studied (Dwi, 2016);

caterpillars and grasshoppers in long bean plants (Khairil, 2017); the pest of the pearls in the rice plant (San, 2016); and the pest of soybean powder (Harinta et al., 2016).

Soursop leaf extract (*Annona muricata*) showed high activity effect of mortality. The value obtained was high enough for inhibiting mortality on leaf caterpillar pests, because soursop leaves have the toxic compounds. The bioactive compounds found in soursop are annonaceous acetogenin. These compounds are found in seeds, bark, fruit and soursop leaves. In soursop leaf, there have been found 18 types of acetogenin and they have been proven in vitro as cytotoxic. Bio-pesticide compounds are expected to have high activity against certain target organisms, in other words, they have a narrow spectrum. Oppositely, the natural predators are hopefully less affected. These compounds are toxic to pest organisms but they do not have any adverse environmental effects and are harmless to humans. Acetogenin compounds have the peculiarity of being contactual poison against pest organisms. Toxic compounds could kill pests quickly (Koleva et al, 2013; do Prado et al., 2014; Riberio et al, 2014; Souza et al., 2017). The chemical compounds in soursop leaves which have contactual poison properties are expected to prevent/control pest of leaf caterpillars in rose apple plants instead of using chemical compounds. The use of water as a solvent for extracting soursop leaves is very appropriate because water is easy to obtain and safe to use.

In the treatment of P1 (soursop leaf extract of 25 ppm concentration), the average of corrected mortality was 6.25. In P2 treatment (soursop leaf extract of 50 ppm concentration), the average of corrected mortality was 6.67. In P3 treatment (soursop leaf extract of 75 ppm concentration), the average of corrected mortality was 1.19. In P4 treatment (soursop leaf extract of 100 ppm concentration), the average of corrected mortality was 3.61. In P0 treatment (negative control), the average of corrected mortality was 0. It can determine the probit value of each treatment. Probit value was used to determine the value of  $LC_{50}$ . The calculation results obtained the  $LC_{50}$  value of 75.16 mg/L (75.16 ppm). The correlation between log concentration of soursop leaf extract and caterpillar mortality was shown at  $R^2$  value of 0.866. The value of  $R^2$  shows that the effect of soursop leaf extract was very significant to eradicate leaf caterpillars (pests) of delima rose apples. This is in line with the Meyer et al. (1982) who reported that an extract showed

toxic activity if it could cause 50% of animals' mortality at a concentration of less than 1000 ppm. Based on the statement, the soursop leaf extract is declared toxic.

The results of the analysis of variance showed that among the treatment groups, the results appeared to be very various in terms of the mortality of the caterpillar. Therefore, it is necessary to conduct further Duncan test to know the difference between each treatment group. Given the soursop leaves extract of 75 ppm and 100 ppm concentration showed no significant difference, and given the soursop leaf extract of 25 ppm concentration was significantly different with the extract of 50 ppm concentration. Moreover, the soursop leaf extract at 50 ppm concentration was significantly different at 75 ppm and 100 ppm concentration. This evidence showed that the giving of soursop leaf extract of 75 ppm concentration is effective, efficient and cheap to eradicate caterpillars. Treatment of 0 ppm (without treatment) showed the lowest mortality index of caterpillar among all treatments. This indicated that without the addition of soursop leaf extract, leaf caterpillar of delima rose apples could not be eradicated.

## CONCLUSION

Based on the research result of the effectiveness of soursop leaf extract (*Annona muricata*) on leaf caterpillar mortality index, it is concluded that:

1. The most effective concentration of soursop leaf extract (*Annona muricata*) in killing leaf caterpillar in delima rose apples is the extract of 100% concentration.
2. Soursop leaf extract (*Annona muricata*) has the effect on mortality index of leaf caterpillars in delima rose apples. The  $LC_{50}$  value of soursop leaf extract was 75,16mg / L.

## REFERENCES

- Ambarningrum, T. B., Pratiknyo, H., & Priyanto, S. (2011). Indeks nutrisi dan kesintasan larva Spodopteralitura F. yang diberi pakan mengandung ekstrak kulit jengkol (*Pithecellobium lobatum* Benth.). *Jurnal Hama dan Penyakit Tumbuhan Tropika*, 9(2), 109-114.
- Amir, A. M. (2009). Pemantauan Resistensi Hama Tembakau terhadap Insektisida. Balai Penelitian Tanaman Tembakau dan Serat. *Malang. J. Ilmiah Tan. Tembakau*, 8(3), 376-380.

- Araar, H., Caboni, P., Simeone, V., & Cavoski, I. (2009). Cinnamon plant extracts a comprehensive physico-chemical and biological study for its potential use as a biopesticide. *Crop protection management in Mediterranean Organic Agriculture*, 39.
- Bardin, M., Fargues, J., & Nicot, P. C. (2008). Compatibility between biopesticides used to control grey mould, powdery mildew and whitefly on tomato. *Biological Control*, 46(3), 476-483.
- Desiyanti, N. M. D., Swantara, I. M. D., & Sudiarta, I. P. Uji efektivitas dan identifikasi senyawa aktif ekstrak daun sirsak sebagai pestisida nabati terhadap mortalitas kutu daun persik (*Myzus persicae* sulz) pada tanaman cabai merah (*Capsicum annum* L.). *Jurnal Kimia*, 10(1), 1-6.
- do Prado Ribeiro, L., Zanardi, O. Z., Vendramim, J. D., & Yamamoto, P. T. (2014). Comparative toxicity of an acetogenin-based extract and commercial pesticides against citrus red mite. *Experimental and Applied Acarology*, 64(1), 87-98.
- Harinta, Y. W., Nugraheni, R., & Setyorini, A. (2016). Pengendalian hama bubuk kedelai (*Callosobruchus analis* f.) dengan biji sirsak (*Annona muricata*). *Agrin*, 20(1), 81-91.
- Hariyanto, P. B. (1991). *Jambu air jenis, perbanyakkan, dan perawatan*. Penebar Swadaya.
- Hasnah, H. (2009). Efektivitas ekstrak buah mengkudu (*Morinda citrifolia* L.) terhadap mortalitas *Plutella xylostella* L. pada tanaman sawi. *Jurnal Floratek*, 4(1), 29-40.
- Hidayati, N. N., & Yuliani, N. K. (2013). Pengaruh Ekstrak Daun Suren dan Daun Mahoni terhadap mortalitas dan Aktivitas Makan Ulat Daun (*Plutella xylostella*) ada Taman Kubis. *Lentera-Bio. Surabaya*, 2, 95-99.
- Julaily, N., & Mukarlina, T. R. S. (2013). Pengendalian Hama pada Tanaman Sawi (*Brassica juncea* L.) Menggunakan Ekstrak Daun Pepaya (*Carica papaya* L.). *Protobiont*, 2(3), 171-175.
- Khairil, M. (2017). Aplikasi ekstrak daun sirsak terhadap serangan hama ulat dan belalang pada tanaman kacang panjang (*Vigna sinensis* L.). *Agrotropika Hayati*, 4(3).
- Koleva-Gudeva, L., Mitrev, S., Maksimova, V., & Spasov, D. (2013). Content of capsaicin extracted from hot pepper (*Capsicum annum* ssp. *microcarpum* L.) and its use as an ecopesticide. *Hemijaska industrija*, 67(4), 671-675.
- Li, S., & Zhihui, C. (2008). *Allium sativum* extract as a biopesticide affecting pepper blight. *International journal of vegetable science*, 15(1), 13-23.
- Mamun, M. S. A., & Ahmed, M. (2013). Prospect of indigenous plant extracts in tea pest management. *International Journal of Agricultural Research, Innovation and Technology*, 1(1-2), 16-23.
- Maryani, I. (1995). Toksisitas Ekstrak Kasar Biji Sirsak (*Annona muricata* Linn.) dan Daun Saliara (*Lantana camara* Linn.) secara Tunggal maupun Campurannya terhadap Larva *Spodoptera exigua* Hubner (*Lepidoptera: Noctuidae*) pada Tanaman Bawang Merah (*Allium ascalonicum* Linn.) di Laboratorium (Doctoral dissertation, Tesis Fakultas Pertanian Universitas Padjadjaran, Bandung).
- Meyer, B. N., Ferrigni, N. R., Putnam, J. E., Jacobsen, L. B., Nichols, D. J., & McLaughlin, J. L. (1982). Brine shrimp: a convenient general bioassay for active plant constituents. *Planta medica*, 45(05), 31-34.
- Moniharapon, D. D., & Moniharapon, M. (2014). Ekstrak Etanol Daun Melinjo (*Gnetum Gnemon* L.) sebagai Antifeedant Terhadap Larva Ulat Grayak (*Spodoptera litura* Fab.) pada Tanaman Sawi (*Brassica sinensis* L.). *Jurnal Budidaya Pertanian*, 10(2), 100-104.
- Morton, J. F. (1987). *Fruits of warm climates*. JF Morton.
- Prabowo, R. (2008). Kajian biopestisida dan pupuk hayati dalam mendukung pengelolaan tanaman tomat secara terpadu. *MEDIAGRO*, 4(1).
- Putri, D. A. (2016). Pengaruh pemberian ekstrak daun kersen (*Muntingia calabura*) terhadap lalat buah *Bactrocera carambolae*; the influence to giving leaf extract kersen (*Muntingia calabura*) against fruit flies *Bactrocera carambolae*. *Al-Kauniyah: Jurnal Biologi*, 9(2), 139-143.
- Ribeiro, L. D. P., Mota, L. H. C., D'alessandro, C. P., Vendramim, J. D., & Júnior, I. D. (2014). In vitro compatibility of an acetogenin-based bioinsecticide with three species of entomopathogenic fungi. *Florida entomologist*, 97(4), 1395-1403.
- Rusdy, A. (2010). Pengaruh Pemberian Ekstrak Bawang Putih Terhadap Mortalitas Keong Mas. *Jurnal Floratek*, 5(2), 172-179.
- Salaki, C. L., Paendong, E., & Pelealu, J. (2012). Biopestisida dari ekstrak daun pangi (*Pangium* sp.) terhadap serangga *Plutella xylostella* di Sulawesi Utara. *EUGENIA*, 18(3), 171-177.
- San Lebang, M., Taroreh, D., & Rimbing, J. (2016). Efektifitas Daun Sirsak (*Annona muricata* L) dan Daun Gamal (*Gliricidia sepium*) dalam Pengendalian Hama Walang Sangit (*Leptocorisa acuta* T) pada Tanaman padi Effectiveness of Soursop Leaf (*Annona muricata* L) and Gliricidia Leaf (*Gliricidia sepium*) to Contr. *BIO-SLOGOS*, 6(2), 51-59.
- Siahaya, V. G., & Rumthe, R. Y. (2014). Uji ekstrak daun pepaya (*Carica papaya*) terhadap larva *Plutella xylostella* (*Lepidoptera: Plutellidae*). *Agrologia*, 3(2), 113-116.
- Souza, C. M., Baldin, E. L., Ribeiro, L. P., Silva, I. F., Morando, R., Bicalho, K. U., ... & Fernandes, J. B. (2017). Lethal and growth inhibitory activities of Neotropical Annonaceae-derived extracts, commercial formulation, and an isolated acetogenin against *Helicoverpa armigera*. *Journal of Pest Science*, 90(2), 701-709.
- Sumartini, S. (2017). Biopestisida untuk Pengendalian Hama dan Penyakit Tanaman Aneka Kacang dan Umbi. *Iptek Tanaman Pangan*, 11(2), 159-165.



- Supriatna, J. (2008). *Melestarian Alam Indonesia*. Yayasan Obor Indonesia.
- Zarins, I., Daugavietis, M., & Halimona, J. (2009). Biological activity of plant extracts and their application as ecologically harmless biopesticide. *Scientific works of the Lithuanian Institute of Horticulture and Lithuanian University of Agriculture*, 28(3), 11.
- Zen-hong, S., Lin, T., Lai, J., Huang, C., Wang, D., & Pan, H. (2007). The industry and progress review on the cultivation and physiology of wax apple with special reference to 'Pink Variety'. *The Asian and Australasian Journal of plant Science and Biotechnology*. *Global Science Book*, 1(2), 48-53.

**DEVELOPMENT OF DIGITAL STORYTELLING-BASED SCIENCE TEACHING MATERIALS TO IMPROVE STUDENTS' METACOGNITIVE ABILITY****N. R. Dewi\*<sup>1</sup>, S. Kannapiran<sup>2</sup>, S. W. A. Wibowo<sup>3</sup>**<sup>1</sup>Department of Integrated Sciences, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia<sup>2</sup>Department of Technical and Vocational Education, Faculty of Technical and Vocational, Sultan Idris Education University, Malaysia<sup>3</sup>SMP N 2 Boja, Semarang, Indonesia**DOI: 10.15294/jpii.v7i1.12718**Accepted: January 15<sup>th</sup>, 2018. Approved: February 15<sup>th</sup>, 2018. Published: March 19<sup>th</sup>, 2018**ABSTRACT**

This study aims to produce digital-based storytelling teaching materials of natural science that can facilitate the students to be able to explore the object of science learning deeply and to improve their metacognitive ability. This research is development research. The samples used are four teachers and 40 junior high school students. The technique of gathering data employed a testing method, documentation study, and questionnaire. Validation is done to determine the feasibility of teaching materials. The research result of the improvement of students' metacognitive ability is measured by using the testing method in the form of pretest and posttest. Pretest and posttest data were analyzed by N-gain and t-test of significance. The result of the research shows that the average percentage of validation result of media expert and material expert is 97,70% and 95,16%. According to experts, all developed products are very feasible to use. The results of metacognitive enhancement (N-gain) for levels 1 to 5 respectively were 0.36; 0.56; 0.49; 0.45 and 0.39. The results of significance test showed that the t-count 7.65 and t-table of 2.03 which that the mean improvement of the metacognitive ability of students is significant. Based on the results of this study, it can be concluded that the teaching materials based on digital storytelling are feasible to be used to improve students' metacognitive ability.

© 2018 Science Education Study Program FMIPA UNNES Semarang

**Keywords:** teaching materials of natural science, metacognitive, digital storytelling**INTRODUCTION**

Curriculum 2013 requires the integration of one field of science with other fields of science. This integration should also be presented in the subject of natural science. Based on the 2013 curriculum, natural science subject at the junior level should be developed as integrative science subjects, not as disciplinary education. It means

that the deliveries of material concepts from various disciplines are presented in an integrated way and not in the separated way (Sholihat, 2015). The use of varied media is needed in the science lesson. This is because the varied learning media can develop students' motivation in learning (Ali, 2009).

Metacognitive competence is ability or mental activity in cognitive structure done by an individual to set up, control, and check his thinking process (Haryani, 2012). Metacognitive

---

**\*Correspondence Address:**

E-mail: noviratnadewi@mail.unnes.ac.id

competence needs to be developed and improved towards students' to improve their high-level skill which will lead to increase education quality (Sumampouw, 2011). The five aspects in metacognitive competence which need to be cultivated to students are: awareness of thinking process and ability to develop it, developing the introduction of thinking strategies, evaluative procedural reflection, transferring knowledge and procedural experiences to other contexts, linking conceptual understanding with procedural experience (McGrigor, 2007; Anderson, 2001).

Flavell states that students' (even people in general) metacognition demands to be developed for the following reasons: (1) students should have a tendency to think a lot, in other words, the more metacognition, the more cognition is needed; (2) students' thought tend to be wrong, thus, good monitoring and arrangement are essential; (3) students should be willing to communicate, explain, and give clear reasons for their thoughts to others and themselves, this activity surely requires cognition; (4) in order to survive and be successful, students have to plan their future and critically evaluate other probable plans; (5) if students are in need of making tough decision, metacognitive skills are demanded; (6) students should have a necessity to infer and tell their psychological event to themselves and others. This tendency to engage in metacognitive activity indicates social cognition (Haryanti, 2012).

The development of the educational world leads teachers to improve their professional skill (Dewi, 2012). Dewi et al. (2017) have researched metacognitive competence and science materials in SMP. It turns out that teachers have not yet had proper knowledge about metacognitive competence, resulting in students' low metacognitive competence. The general type of science learning materials found are in the form of printed, visual, and multimedia, but there is no such as audio-visual like film. In fact, the film is included as learning materials.

Media could be one of the solutions to overcome time and cost inefficiency in science learning. Educators need media to communicate designed information during learning process so that it will be more realistic and fun, as what Skouge found in his research about the utilizing of digital storytelling in the learning process. According to Maddin (2011), digital storytelling is the art of storytelling by combining various digital multimedia, such as text, images, narrative recordings, audio, video, and music, resulting in an interesting short film to present information on a particular topic. The information or stories

presented can be historical events, personal lives, or other stories in a short duration of time. What it means for digital storytelling here is learning media in the form of an educational film that depicts the daily life of learners, containing several topics on a material. Akhlis & Dewi (2014) has developed website-based science learning media. However, videos on the website are just downloaded from other sources, instead of designed videos for science learning. Therefore, separate student worksheets are required to make the videos relevant to the topic. The upcoming idea after the research ends is, why don't we create customized videos tailored to the science learning which are also aided by question guidance focusing on the learned materials?

Researchers that refer to the development of ICT-based and conventional-based science learning media have been done before. Wulandari et al. (2013) have developed a natural science learning video. Pramana, W. D. & Dewi, N. R. (2014) developed an E-Book of Integrated Natural Science. Maharani & Dewi (2015) also have developed a website learning media, and Syahroni et al. (2016) have developed an online digital module (DIGIMON). Moreover, ICT-based development of teaching materials using traditional games has also been developed by Dewi & Akhlis (2016). Also, developed teaching media are not intended for students' metacognitive development. These studies still focus on learning outcomes only. In its development, researchers adopt the importance of students' awareness in learning that can be seen through their metacognitive abilities. The research which concerns with metacognitive ability has been done by some researchers like Christop, (2006) who examines the rules of metacognitive in learning to solve problems. Veenman et al. (2006) studied metacognitive concepts and methodologies in learning. Shannon (2008) used metacognitive strategies and learning styles to establish self-reliance in learning. Saraswati et al. (2011) used metacognitive strategies to improve students' higher-order thinking skills. Additionally, by referring to the results of research by Skouge et al. (2009) investigating the role of digital storytelling to students so that students appreciate cultural diversity through reflection of experiences presented in comic/storybook, the development of this research also utilizes IT-based digital storytelling as instructional materials designed specifically to improve students' metacognitive ability. Metacognitive ability is a capability or mental activity in the cognitive structure that a person consciously takes to regulate, control, and examine his thinking process

(Haryani, 2012). Metacognitive abilities need to be developed and improved in students to improve the high-level skills of students that will lead to increase the quality of education (Sumampouw, 2011).

The development of the educational world leads a teacher to improve the ability or professional teacher (Dewi, 2012). Dewi et al. (2017) have researched about metacognitive ability and teaching materials of science in SMP. Teachers do not yet know metacognitive ability so that the metacognitive ability of students is still relatively low. The types of science teaching materials, in general, are in the form of printed materials, visual and multimedia, but there are no science teaching materials such as the visual type of film. The film is included in the learning media. Media can be one solution to overcome the inefficiency of time and cost in science learning. Media is needed to inform messages that have been designed by educators so that learning is more realistic and fun, as Skouge's research on the use of digital storytelling in learning. Maddin (2011) stated that digital storytelling is the art of storytelling by combining various digital multimedia, such as text, images, narrative recordings, audio, video, and music, resulting in an interesting short film to present information on a particular topic. The information or stories presented can be historical events, personal lives, or other stories in short duration of time. The digital storytelling here means a learning media in the form of educational films that depict the daily life of learners in which there are several topics on a material. Akhlis & Dewi (2014) have developed Web-based IPA learning media, but the videos used are downloaded videos that are not specifically designed for science learning. Therefore, separate student work sheet to make the video can be utilized in learning.

The idea that comes after the end of the study is making a special video to support the science material with the questions guide focused on the material to be learned.

Based on the description, the researchers formulate several problems, among others: (1) how is the feasibility of learning materials based on science digital storytelling?; and (2) is the use of digital storytelling-based learning materials in science teaching effective in improving students' metacognitive abilities?

## METHODS

The development and research model used is a modification of Sugiyono's development step (2015). The data taken are the feasibility and effectiveness of digital storytelling-based science materials. Data collection method used was questionnaires and tests. The subjects of this study are the seventh-grade students of SMP as many as 40 children. The questionnaire method is intended to determine the feasibility of the developed teaching materials. The questionnaire instruments used are a validation questionnaire for media experts and material experts used in the design validation stage. Before being used to retrieve the data, the questionnaire instrument was first validated by an expert and has been declared valid. The validation questionnaires of digital storytelling-based science materials by media experts include four aspects; software engineering, audio communication, visual communication, etc. Whereas the validation questionnaires material experts consist of 6 aspects; material scope, accuracy, recency and contextuality, presentation, supportive presentation, and learning presentation.

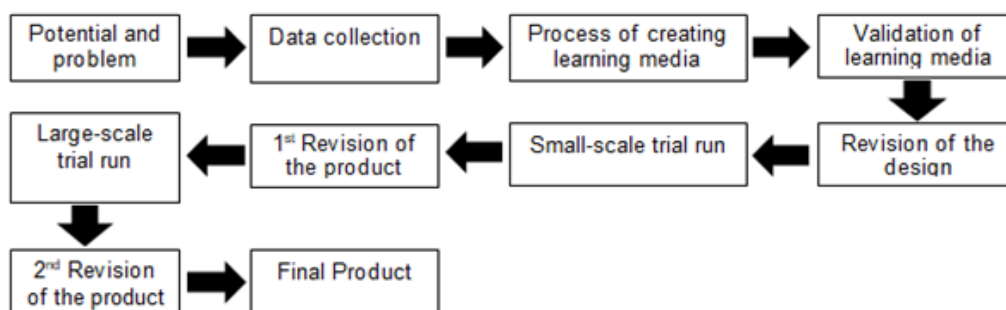


Figure 1. Research Design Development (Sugiyono, 2009 Modified Version)

Tests were assigned to measure students' metacognitive improvement. As Haryani (2012) states that metacognitive competence could be measured by the test as a metacognitive indicator of conceptual mastery. There are five metacognitive indicator levels employed to arrange the test questions, among them are: (1) awareness of thinking process and ability to describe it; (2) developing the introduction of thinking strategies; (3) systematically procedural reflection; (4) transferring knowledge and procedural experiences to other contexts, and (5) linking conceptual understanding with procedural experience. The test method used pre-test and post-test in the form of multiple choice with reasons. The test instruments used are valid and reliable. Before being used in pre-test and post-test, the first problem is tested on students who have received the materials of the classification theme to obtain validity, and reliability of the question. The improvement of students' metacognitive abilities was calculated using N-gain (Hake, 1999) and t-test of significance.

## RESULTS AND DISCUSSION

The development of contextual-based digital storytelling media must be validated or assessed by experts by predetermined aspect and criteria. Assessment of media development that has been done is through one stage or two stages according to the assessment of the experts to the media till the media are proved to be feasible. Media is said to be suitable to be applied in learning if the obtained score is > 62.50% (Arikunto, 2012) and there is no revision. Questionnaire validation of digital storytelling-based science learning materials by media experts consists of 4 aspects of namely software engineering, aspects of audio communication, visual communication aspects, and other aspects. Questionnaire of material validation consists of 6 aspects: material coverage, material accuracy, up-to-date and contextual, presentation aspect, supporting the material presentation, and presentation of learning. The results of the assessment of media experts and material experts on developed materials are presented in figure 2.

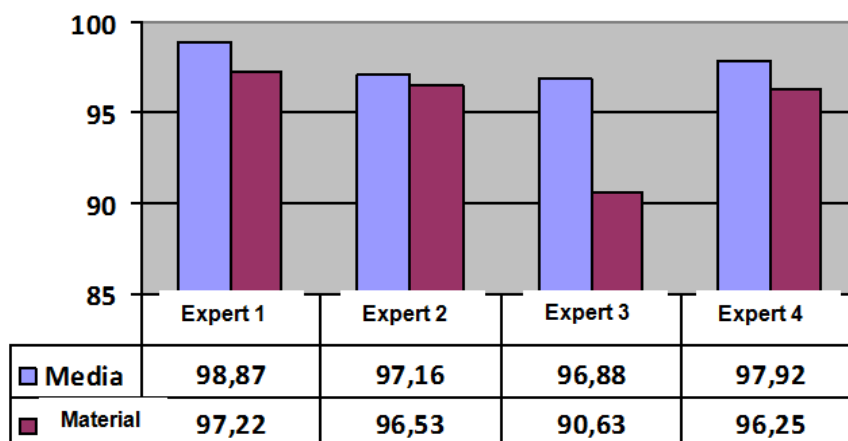


Figure 2. Results of Expert Validation

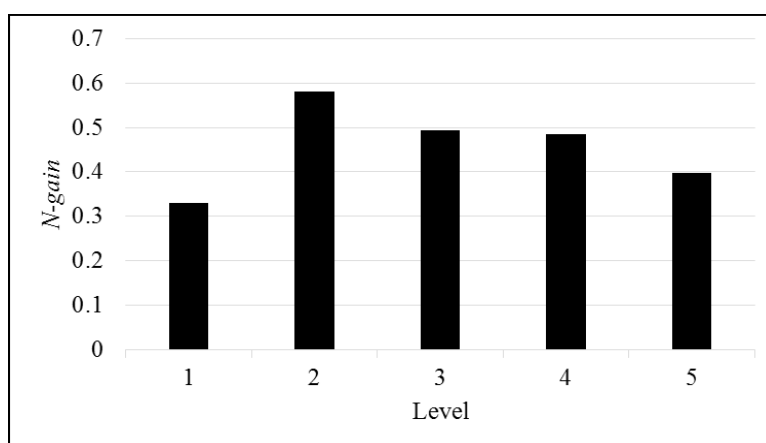
Figure 2 shows that the expert validation results for digital storytelling-based science materials get the excellent score. The average percentage of media expert judgments provides 97.70% with very reasonable criteria. The materials experts also provide a very feasible assessment with an average percentage of 95.16%. The validation of these teaching materials produces teaching materials with very reasonable criteria, but the three experts stated that learning materials need to be improved. Things to improve include: (1) addition of movie title; (2) addition of movie characters; (3) type and color of text made cheerful; (4)

extended text duration; (5) text color and background contrast; (6) the writing of the narrative is tidied; (7) the selection of back sound is adjusted; (8) some hardened character sounds; (9) fixes typing errors. The suggestions are used as guidance in the improvement of teaching materials to produce appropriate teaching materials. The title of a digital storytelling movie needs to be added with the aim that students know the outline of the material to be submitted in every movie. In addition, the existence of the title is one of the components that must exist in the media digital storytelling is good, namely point of view (Robin,

2008). Therefore, each film on science-based digital storytelling materials has been added to the title, so students gain an initial knowledge of the story content of the teaching materials.

Based on the results obtained by the students on the test before and after the implementation of learning using digital storytelling-based science materials on the theme of classification, then the researcher performed calculations and comparisons to determine whether or not there is an increase in the metacognitive ability of students before and after learning using science-

based digital storytelling materials. The increased metacognitive ability of students was analyzed by using N-gain and significance test. Based on the N-gain calculation, students' metacognitive abilities have improved. There are three categories of increase in N-gain, i.e., low, medium, and high. The increased metacognitive ability of students can also be viewed from each level. There are five levels of metacognitive ability. Figure 3 shows the ability improvement of students' metacognitive ability on each level



**Figure 3** The Improvement of Students' Overall Metacognitive Ability for Each Level.

Note:

1. Realizing the thinking process and being able to develop it.
2. Developing the introduction of thinking strategy
3. Reflecting the procedure in an evaluative way
4. Transferring the knowledge experience and procedures of other contexts
5. Relating the conceptual understanding of procedural experience

To know the significant improvement of students' metacognitive ability, the researchers carried out significance test with the

t-test at  $\alpha = 5\%$ . Data and calculation of the students' metacognitive ability improvement can be seen in table 1.

**Table 1.** Significance Test of the Increase of Students' Metacognitive Ability

Data	Average	Md	Sx <sup>2</sup> d	T <sub>count</sub>	t <sub>table</sub>	Category
Pre-test	44,07					
Post-test	67,75	2368333	6369,73	7,65	2,03	Significant

Based on table 1. After calculation through t-test, the overall metacognitive ability of students has significant improvement, because  $t_{count}$  is bigger than  $t_{table}$ .

Measurement of students' metacognitive improvement is done by giving test questions. Haryani (2012), stated that metacognitive ability

could be measured by using tests as mastery of concepts with metacognitive indicators. The test problems given are 30 questions in the form of multiple choices with reasons. There are five levels of metacognitive indicators used to make test questions.

Each level of metacognitive ability is calculated by the increase (N-gain) through the pre-test and post-test scores obtained by each student. Based on the results shown in Figure 2. it can be seen that overall level 1 of metacognitive ability got the value of 0.36 with the low category, level 2 got the value of 0.56, level 3 and 4 got the value of 0.49 and 0, 45, while level 5 got a value of 0.39. Level 2, 3, 4, and five were included in the medium category. This indicates that the learning successfully improves students' metacognitive abilities on the theme of classification. The metacognitive ability level that experienced the highest increase was the second level. The result is achieved by students' discussion activity to solve the problem during the learning process. As Nugroho *et al.* (2013) said that students are greatly motivated when they involve directly in the learning process which utilizes media and discussion method. There is a component called *dramatic questions* on digital storytelling materials. *Dramatic questions* consist of provoking questions for students to lead and curiously find out information to solve problems (Engle, 2014).

The first level of metacognitive ability is to be aware of the process of thinking and being able to describe it. The indicator used for the first level is knowing what and how and identifying information. The indicator of the first level of metacognitive ability has the intention that the student can identify information from the case presented and to know what the information is and how the case in the information. There is a *point of view* component on *digital storytelling* video. It contains preliminary information of the story, showing the information that students will get from the *digital storytelling* video (Engle, 2014). The first level of metacognitive ability in this study experienced the lowest increase. This can be caused by several things, such as within the post-test when the students are less focused in understanding the problem so that the information contained in the problem cannot be digested well by the students. In addition, the first level in this metacognitive ability is the most basic level. The students frequently do the problem, so that during the learning, there is only a little explanation on how to identify information so that the results obtained by students are not maximal.

The second level of metacognitive ability is developing an introduction to thinking strategies. Indicators taken at the second level are deciding the most appropriate operation and describing the specific operation sequence. This second level leads the students to take the appropriate steps or ways for each problem. In addition, based on

the indicators at level 2, the students are meant to be able to choose and determine action. The increase in N-gain at level 2 shows the highest increase. The highest increase obtained at this level can occur because, during the learning process, the student is assigned to discuss in solving the problem. Hughes (2014) stated that critical-thinking students have alternative thinking and a rational mindset by always finding and explaining a solution to the problem. According to Nugroho *et al.* (2013), students are greatly motivated when they involve directly in the learning process which utilizes media and discussion method. There is a component called *dramatic questions* on digital storytelling materials. The *dramatic questions* consist of provoking questions for students to lead and curiously find out information to solve problems (Engle, 2014)

Reflecting evaluatively the procedures is the third level in metacognitive ability. One indicator used at this level is to compile and interpret the data. Pictures and animations of the *digital storytelling* video can help students in comprehending the materials. The problems given to determine the effectiveness of science learning tools developed in improving the metacognitive ability of students are in the form of data. Problems in the form of data to make students more accurate in solving problems faced. According to the observations made, when students are working on questions in the form of data, it takes a relatively longer time than the usual problems. Difficulty in reading the data on the given problem makes the students find difficulty in working on the problem so that the increase of metacognitive ability at level 3 is classified in the medium category.

Level 4 of metacognitive ability in this study is transferring knowledge and procedural experience in other contexts. Just like level 3 that takes an indicator, level 4 also takes one indicator that is developing a procedure for the same problem. Success at level 4 is demonstrated in the students' ability to answer questions and gives the right reasons for the questions made with indicators at level 4. The work of the problem must be by observing the digital video storytelling. Students should be able to connect what they see with the problem they face. The questions present data in the form of the chart where students must be able to complete the chart before the students can answer the intended problem. Level 4 belongs to the moderate category. Students are said to have reached this level because after learning using Digital Storytelling-based science materials, there is increased activity in asking and answering questions.

Digital storytelling video contains materials which could assist students in answering questions on Independent Worksheets (IW). Hence, students should carefully watch the digital storytelling video before working on the IW. It is expected that students be able to relate what they have seen to the questions they find on the IW. Digital storytelling video is a contextual learning medium which can drive students in independently seeking information. Charts are provided on IW. Therefore, students need to complete it before answering the questions.

One component of Digital Storytelling media is a dramatic question where in the media, there are several questions. These questions provoke students to ask questions and answer questions, resulting in discussion in learning. Students are more motivated in learning when involved directly in the learning process that utilizes the media with the help of discussion methods (Nugroho et al., 2013). Digital storytelling can also increase students' learning motivation (Yang, 2012)

The last level of improvement in metacognitive ability is level 5 (linking conceptual understanding with procedural experience). The indicator used is linking observation data by discussing and selecting important information used in solving the problem. The success of level 5 is shown on the accuracy of students in answering the questions and reasons that students give to the test questions. Digital storytelling videos contain materials that help students in completing practice questions and test questions appropriately. Digital video storytelling on every lesson can improve students' metacognitive ability because by observing the digital video storytelling video, the students can find the important information they need.

Suwardy et al. (2013) stated that Science Digital Storytelling can improve students' ability in relating the theories studied in the cases experienced. The statement is in line with Botturi et al. (2014) and Niemi et al. (2014) who explained that the use of Science Digital Storytelling media in learning could improve the quality of students and grow the skills of 21st-century students. The category of metacognitive enhancement of students at this level belongs to the medium category. The learning process through observing the digital video storytelling when the students should watch, observe and understand the material in the video should be able to assist students in solving the given problem. Students will be more creative in solving a problem when students are directly

involved in everyday life (Sambada, 2012).

Metacognitive capabilities that have been calculated through N-gain have increased. The increase is then analyzed again using t-test. The t-test is a test of significance to determine whether the improvement of students' metacognitive ability through digital-based science storytelling materials on a classification theme is significantly developed or not. Additionally, this research also found how big the value of significance is if it is proven that the metacognitive ability increased. Based on the calculation in Table 1, it can be seen that the improvement of students' metacognitive competence through a guided inquiry-based science learning device with digital storytelling aid on thematic classification. The results are obtained through a series of research process development of teaching materials based on science digital storytelling on the theme of classification that has been done to give a good influence on students' metacognitive ability. Rahmawati (2015), stated that learning using digital media storytelling can also improve students' achievement. Iskandar (2016), stated that the relationship between the belief in students with the intelligence, awareness, and knowledge of the level of tasks that he did and how to overcome them can be regarded as metacognitive ability. Flavell suggests that even students' metacognition generally needs to be developed for the following reasons: (1) students should have a tendency to think a lot, in the sense that more metacognition requires more cognition; (2) students' thinking can be erroneous and tends to be wrong, and in these circumstances require good monitoring and arrangement; (3) the student must be willing to communicate, explain, and give clear reasons for his or her thoughts to other students as well as to himself, this activity, of course, requires metacognition; (4) to survive and be successful, students need to plan for the future and critically evaluate other plans; (5) if the student has to make a tough decision, it will require metacognitive skills; and (6) the student must have the need to infer and explain psychological events on himself and others. The tendency to engage in such metacognitive actions indicates social cognition (Haryani, 2012).

## CONCLUSION

Based on the results of research, it can be concluded that the Digital Storytelling-based science teaching materials that have been developed is declared as appropriate for teaching mate-



rials of SMP class VII with the average percentage score of 97,70% at media aspect and 95,16% at material aspects. Digital Storytelling-based science teaching materials on classification themes have been developed effectively to significantly increase metacognitive abilities.

## REFERENCES

- Akhlis, I., & Dewi, N. R. (2014). Pengembangan Perangkat Pembelajaran Science Berorientasi Cultural Deviance Solution Berbasis Inkuiri Menggunakan ICT untuk Mengembangkan Karakter Peserta Didik. *Jurnal Pendidikan IPA Indonesia*, 3(1), 86-94.
- Ali, M. (2009). Pengembangan media pembelajaran interaktif mata kuliah medan elektromagnetik. *Jurnal Edukasi Elektro*, 5(1), 11-18.
- Arikunto, S. (2012). *Dasar-Dasar Evaluasi Pendidikan*. Jakarta: Bumi Aksara.
- Botturi, L., Bramani, C., & Corbino, S. (2014). Digital storytelling for social and international development: from special education to vulnerable children. *International Journal of Arts and Technology*, 7(1), 92-111.
- Christoph, L. H. (2006). *The role of metacognitive skills in learning to solve problems*. SIKS.
- Dewi, N. R. (2012). Kompetensi Mahasiswa IPA Dalam Merencanakan Penelitian Ilmiah Bidang Sains. *Jurnal Pendidikan IPA Indonesia*, 1(1), 71-74.
- Dewi, N. R., & Akhlis, I. (2016). Pengembangan Perangkat Pembelajaran IPA Berbasis Pendidikan Multikultural Menggunakan Permainan untuk Mengembangkan Karakter siswa. *Unnes Science Education Journal*, 5(1), 1098-1101.
- Dewi, N. R., Wibowo, S. W. A., & Savitri, E. N. (2017). The Analysis of Science Learning Sources Reviewed from the Meta-Cognitive Ability of The VII Grade the Students of SMP Negeri 2 Boja. *Unnes Science Education Journal*. 6(2), 1625-1632.
- Hake, R. R. (1999). Analyzing change/gain scores. *Unpublished.[online] URL: <http://www.physics.indiana.edu/~sdi/AnalyzingChange-Gain.pdf>*. Accessed on August, 12, 2017.
- Haryani, S. (2012). Membangun Metakognisi dan Karakter Calon Guru Melalui Pembelajaran Praktikum Kimia Analitik Berbasis Masalah. *Skrripsi. Semarang: FMIPA Universitas Negeri Semarang*.
- Hughes, C. (2014). Theory of Knowledge aims, objectives and assessment criteria: An analysis of critical thinking descriptors. *Journal of Research in International Education*, 13(1), 30-45.
- Iskandar, S. M. (2016). Pendekatan keterampilan metakognitif dalam pembelajaran sains di kelas. *ERUDIO (Journal of Educational Innovation)*, 2(2), 13-20.
- Kemendikbud. (2013). *Kurikulum 2013 Kompetensi Dasar Sekolah Menengah Pertama (SMP)/ Madrasah Tsanawiyah (MTs)*. Jakarta: Kementerian Pendidikan dan Kebudayaan.
- Maddin, E. (2011). Using TPCK with Digital Story Telling to Investigate Contemporary Issues in Educational Technology. *Journal of Instructional Pedagogies*, 2-6.
- Maharani, D. W., & Dewi, N. R. (2015). The Implementation of Science Inquiry-Based Website Oriented by Cultural Deviance Solution to Instill Students' Character and Independence. *Jurnal Pendidikan IPA Indonesia*. 4(1), 25-30.
- Niemi, H., Harju, V., Vivitsou, M., Viitanen, K., Multisilta, J., & Kuokkanen, A. (2014). Digital storytelling for 21st-century skills in virtual learning environments. *Creative Education*, 5(9), 657-671.
- Nugroho, A. P., Raharjo, T., & Wahyuningsih, D. (2013). Pengembangan Media Pembelajaran Fisika Menggunakan Permainan Ular Tangga Ditinjau dari Motivasi Belajar Siswa Kelas VIII Materi Gaya. *Jurnal Pendidikan Fisika*, 1(1), 11-18.
- Pramana, W. D., & Dewi, N. R. (2014). Pengembangan E-Book IPA Terpadu Tema Suhu dan Pengukuran untuk Menumbuhkan Kemandirian Belajar Siswa. *Unnes Science Education Journal*, 3(3), 602-608.
- Rahmawati, R. N. (2015). Penggunaan CD Interaktif dan *Digital Storytelling* Berbasis Kontekstual sebagai Media Pembelajaran Matematika. *Seminar Nasional Matematika dan Pendidikan Matematika*. Yogyakarta: Universitas Negeri Yogyakarta.
- Robin, B. R. (2008). Digital storytelling: A powerful technology tool for the 21st century classroom. *Theory into practice*, 47(3), 220-228.
- Sambada, D. (2012). Peranan Kreativitas Siswa Terhadap Kemampuan Memecahkan Masalah Fisika dalam Pembelajaran Kontekstual. *Jurnal Penelitian Fisika dan Aplikasinya (JPFA)*, 2(2), 37-47.
- Sastrawati, E., & Rusdi, M. Syamsurizal. (2011). *Problem-Based Learning, Strategi Metakognisi, dan Keterampilan Berpikir Tingkat Tinggi Siswa*. *Tekno-Pedagogi, ISSN*, 1-14.
- Shannon, S. V. (2008). Using metacognitive strategies and learning styles to create self-directed learners. *Institute for Learning Styles Journal*, 1(1), 14-28.
- Sholihat, N. (2015). *Pengaruh Pembelajaran Ipa Terpadu Tipe Integrated Terhadap Penguasaan Konsep Dan Berpikir Kritis Siswa Smp Pada Topik Tekanan* (Doctoral dissertation, Universitas Pendidikan Indonesia).
- Skouge, J. R., & Rao, K. (2009). Digital Storytelling in Teacher Education: Creating Transformations through Narrative. *Educational Perspectives*, 42(1-2), 54-60.

- Sugiyono. (2015). *Metode Penelitian Pendidikan: Pendekatan Kuantitatif, Kualitatif, dan R & D*. Bandung : Alfabeta.
- Sumampouw, H. M. (2011). Keterampilan Metakognitif dan Berpikir Tingkat Tinggi dalam Pembelajaran Genetika (Artikulasi Konsep dan Verifikasi Empiris). *Bioedukasi: Jurnal Pendidikan Biologi*, 4(2), 23-39.
- Suwardy, T., Pan, G., & Seow, P. S. (2013). Using digital storytelling to engage student learning. *Accounting Education*, 22(2), 109-124.
- Syahroni, M. W., N. R. Dewi & Kasmui. 2016. The Effect of Using Digimon (Science Digital Module) with Scientific Approach to The Visualization of Students' Independence and Learning Results. *Jurnal Pendidikan IPA Indonesia*. 5(1), 116-122.
- Veenman, M. V. J. dkk. (2006). Metacognition and Learning: Conceptual and Methodological Considerations. *Springer*. 1(1): 3-14.
- Wulandari, F. R. A., Dewi, N. R., & Akhlis, I. (2013). Pengembangan CD Interaktif Pembelajaran IPA Terpadu Tema Energi dalam Kehidupan untuk Siswa SMP. *Unnes Science Education Journal*, 2(2), 262-268.
- Yang, Y. T. C., & Wu, W. C. I. (2012). Digital storytelling for enhancing student academic achievement, critical thinking, and learning motivation: A year-long experimental study. *Computers & education*, 59(2), 339-352.



## TEACHERS' PERFORMANCE IN SCIENCE LEARNING MANAGEMENT INTEGRATED WITH CHARACTER EDUCATION

**B. Isdaryanti<sup>\*1</sup>, M. Rachman<sup>2</sup>, Y.L. Sukestiyarno<sup>3</sup>, T. S. Florentinus<sup>4</sup>, Widodo<sup>5</sup>**

<sup>1,2,3,4</sup>Post Graduate School, State University of Semarang

<sup>2</sup>Sultan Agung Islamic University

DOI: 10.15294/jpii.v7i1.12887

Accepted: December 23<sup>rd</sup>, 2017. Approved: February 15<sup>th</sup>, 2018. Published: March 19<sup>th</sup>, 2018

### ABSTRACT

The research aims at revealing the performance of teachers in science learning management integrated with character education. This study employed qualitative research method. Based on the result of the t-test of the correlation coefficient, this study obtained t value 4,210 with significance 0,001. The significance value 0,001 < 0,05 showed that there is influence from teachers' performance in arranging learning media integrated with character education to the teachers' performance in science learning. The conclusion of research stated that the performance of science teachers in junior high schools in Semarang City in integrating character education is categorized into a very good category with average score 85,05.

© 2018 Science Education Study Program FMIPA UNNES Semarang

Keywords: teachers' performance, science education system, character education

### INTRODUCTION

The word "teacher" in Javanese cultural terms has a philosophy of "digugu" and "ditiru" (imitated). The term "digugu" implies that a teacher must possess sufficient competencies, while the term "ditiru" (imitated) implies that teachers' personality should have good character (Zulfikar, 2009; Saddhono & Rohmadi, 2014). The good competence and character of teachers can result in better performance in the quality of learning. In fact, qualified teachers will affect on improving the test scores of learners, providing an emotionally supportive environment that contributes to the social and emotional development of learners, managing classroom behavior, delivering accurate content, and supporting critical thinking

(Blazar, 2017; Cohen, 2011; Pianta & Hamre, 2009). The higher the competence and character of the teacher, the more qualified achievement of the teachers' performance. The high teachers' performance and achievement will determine the civilization character of a nation in the future (Hajar, 2017).

The performance of science teachers in Indonesia is inseparable from existing regulations. In line with the Act No. 20 of 2003 on National Education System in Article 3 which reads "National education has a function to develop the ability and instill the character and civilization of dignified nation in order to educate the nation. Moreover, it aims to develop the potential of learners in order to become a human being who believes and cautious to God Almighty, has a noble character, healthy, knowledgeable, capable, creative, independent, and become a democratic and responsible citizen. " The article shows that the

\*Correspondence Address  
E-mail: barokahis@yahoo.co.id

performance of teachers in carrying out the task of learning is not only to transfer knowledge (cognitive), but also instill the character education to learners. However, realizing the goal of national education apparently faces many problems. For example, the case of bullying in school.

The problem of the learners' character becomes an important part that must be strengthened through science learning. This is supported by the research results by Sardjioa & Hapzi (2017) who integrated the characters in learning Science through the process skills activities that can strengthen scientific attitudes. In the field of learning in Indonesia, originally character education is charged to two subjects, namely religion and civics. However, in reality, the instilling process and character formation of learners are not sufficiently integrated through a particular lesson but need to be integrated into all the lessons (Judiani, 2010; Ahmadi et al., 2017). There are several things that make character education do not optimal if it is only integrated through two lessons, namely: (1) the two subjects tend to only provide knowledge about the values through the subject matter/substance; (2) learning activities in both subjects are generally not sufficient, encouraging the internalization of values to each learner so that they behave formidably; and (3) the two subjects are not sufficiently sustained in the instilling process of the learners' character because the instilling process of character requires a habituation that will become a culture and morals for learners (Khusniati, 2012; Akhwan, 2014; Julaiha, 2014).

The disadvantages of character education can at least be parsed by involving more subjects, even all subjects. This refers to Koesoema (2012) which suggests that there are four ways in understanding character education, namely: (1) character education as a special subject; (2) character education as a grouping of subject; (3) character education as a requirement of the state; (4) character education as the process of education itself. Instilling good characters to the learners is not new. The study of various weaknesses and advantages of each model of character education has been obtained to the present selection of education which is done through the integration of various subjects. One of them is the integration of character education carried out in science learning.

The selection of science lessons integrated with character is in line with the challenges of the 21<sup>st</sup> century with its rapid development of technology applied in various areas of life in society. Therefore, it is necessary to find a way

of learning that can prepare learners who have literacy on science and technology and who are able to think comprehensively in solving real-life problems. Therefore, learners are required to master science in an integrated manner (Koballa & Chiapetta 2010; Parmin et al., 2015).

Such an IPA learning substance provides an opportunity for character education to provide guidance on problem-solving in real life. That is, solving the problems generated through learning science is not necessarily rigid and can be harmful to socio-cultural conditions. Only with character education, various issues in the community can be resolved peacefully by referring to the principles of science. These two relationships should be applied in science learning in schools. Thus, the implementation of science learning integrated with character education can be carried out by the teachers.

Referring to the background of this study, the problem in this study is; How is the performance of teachers in the science learning management integrated with character education? The data of the teachers' performance analyzed in this research is science teachers at junior high school in Semarang City. Teacher performance aspects analyzed in this research include; the ability of teachers in preparing lesson plans, implementing learning, and assessment of learning. The objective of this research is to see teachers' performance in science learning integrated with character education. The success and the various weaknesses of the policy of applying character education to various subjects can at least be understood. Therefore, the teacher's performance in the science learning management integrated with character education has an urgency in determining the implementation of character education policy which up to now is still being questioned by various parties.

## METHODS

This research employed qualitative research. The data are teachers' performance in science learning management integrated with character education that includes planning, implementation, and assessment phase. Therefore, the sources of data in this study are 52 science teachers from 26 schools in Semarang City. The school categories in this study are heterogeneous from those located in downtown and suburbs. Semarang city is chosen as the research site because it is the capital of Central Java Province. Semarang city can be used as a barometer of character education quality with geographic ty-

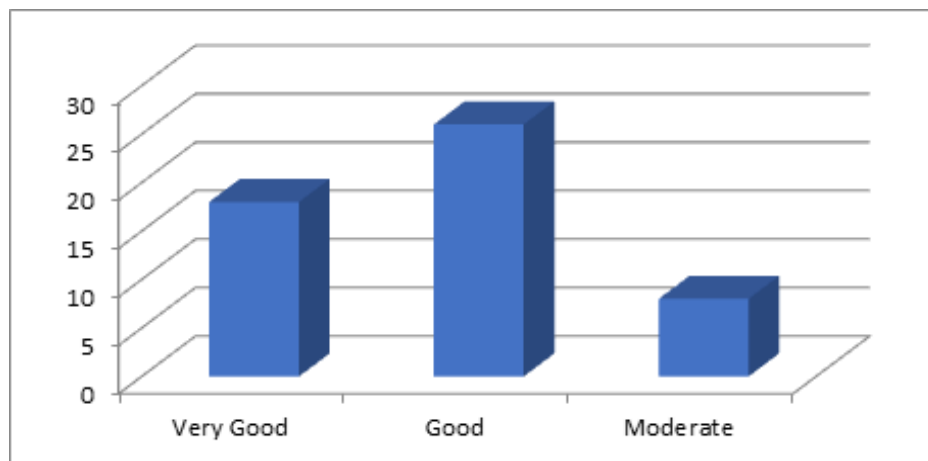
pology and varied school quality. To complete the performance data of junior high school teachers in science learning management integrated with character education, documentation studies on learning tools in a class were developed to meet the availability of valid and reliable data.

Data were obtained by using questionnaire instruments, interviews, guidelines and documentation studies. Data analysis is done by following the logic of qualitative approach. The correlation coefficient t test is done in this research to determine whether or not there is an influence of teachers' performance in arranging integrated learning tool with character education in science learning. The performance of Science Teachers in Semarang City in integrating charac-

ter education is categorized into four groups: excellent, good, sufficient, and lacking. Data analysis employed a qualitative approach which refers to Sugiyono (2012).

## RESULTS AND DISCUSSION

The national commitment to the need for character education is part of the mandate of the national act that should be implemented. Khusniati (2012) states that the way of integrating character education in the learning process is carried out from the planning, implementation, to the evaluation of learning. The performance for aspects of learning planning of the 52 science teachers in this study is presented in figure 1.



**Figure 1.** Science Teachers' Performance in Semarang City in Planning Science Learning Integrated with Character Education

In preparing a learning plan that integrates the character which is done by 52 junior high school teachers in Semarang City, 18 teachers perform very well, 26 teachers perform well, and 8 teachers perform moderately. None of them performed inadequately. Teachers' performance in learning management integrated with character education can be seen from the analysis stage of basic competence, syllabus development, preparation of learning, implementation plan, and preparation of teaching materials. This stage is the most crucial stage in science learning management integrated with character education. The success and failure of integrated science learning is highly dependent on the planning (Krajcik, et al., 2008 & 2014). This role of teachers in planning should be based on the goals integrated with character education.

Starting from the Basic Competence Analysis, this activity is done to select the character values that match the basic competence which is going to be used. The development of syllabus is done by revising the syllabus provided by the government by giving insertion of character values on the formulation of objectives, indicators, learning steps, and assessment. Furthermore, the preparation of teaching materials is done by selecting teaching materials that contain character education if the resource is available. However, if the sources are not yet available, teachers could develop their own teaching materials to be integrated with character education. The following table presents the planning stage of teachers' performance in science learning management integrated with character education.

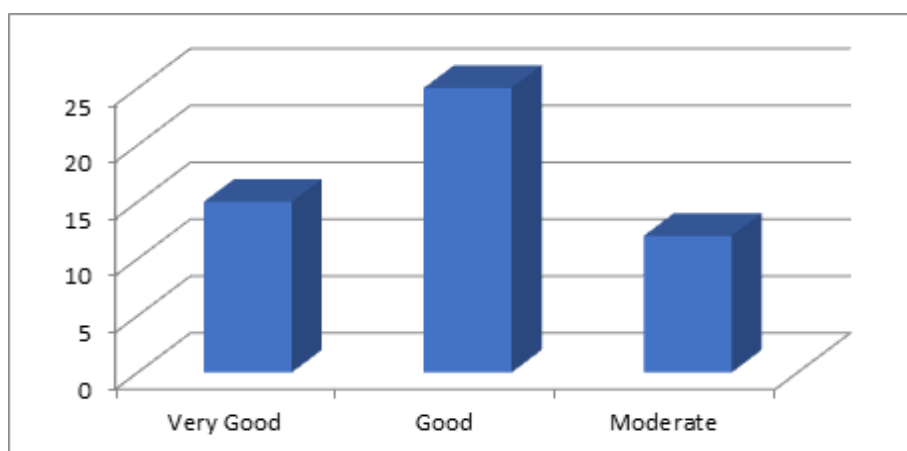
**Table 1.** Teacher Performance in Planning Stage of Science Learning Integrated with Character Education

Teacher Performance	Good (%)	Very Good (%)
Analysis of basic competence of learning science integrated with character education	92	8
Development of science learning syllabus integrated with character education.	92	8
Preparation of the implementation plan of learning science integrated with character education.	92	8
The development of science teaching materials integrated with character education	68	32
Preparation of assessment of science learning outcomes integrated with character education	82	18

At the planning stage, teachers' performance in science learning integrated with character education is more directed to the fulfillment of documents for administration completion. At this level, the performance of teachers is said to be very good in meeting the standards of planning on learning management. Kartowagira (2011) states that preparation of administrative documents at this stage of planning is a part of

competence that is always honed and developed from undergraduate, professional education, and other types of training/workshop. Thus, the performance at this stage of planning is assured to have met the established standards.

In terms of the aspects of learning implementation, the performance of the 52 science teachers in this study is presented in figure 2.

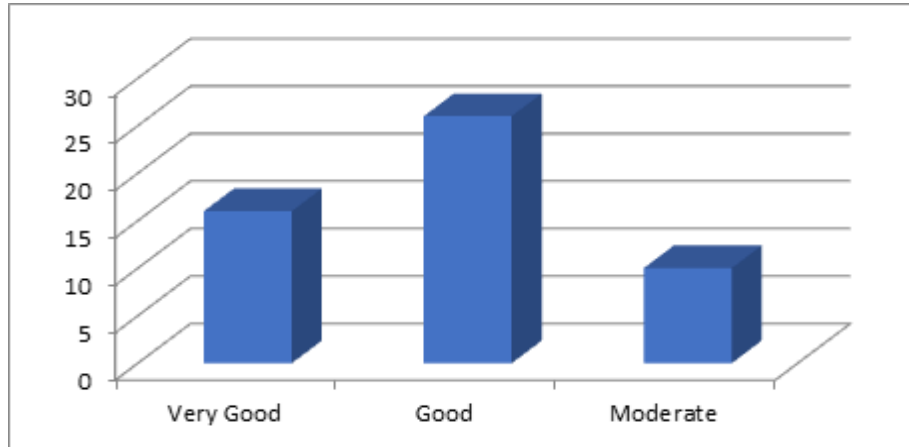
**Figure 2.** Performance of Science Teachers in Semarang City in Implementing Science Learning Integrated with Character Education

The research subjects were 52 teachers of junior high school, 15 people performed very well, 25 performed well, and 12 performed moderately, while underperformers were not found in the results of this study. This stage is the implementation stage of the planning stage. This stage consists of preliminary activities, core activities, and closing activities. From preliminary activities to closing activities, the conducted learning activities were already interesting and well-presented.

However, there are some gaps that teachers forget about when teaching. Instructions for performance are minimally delivered and the assessed attitudes are not explained first. Teachers seem to entrust their assessment to students. Supposedly, teachers have separate judgments when the learners are following the lesson. This deficiency is due to the fact that there are still teachers who do not yet have a good understanding of the science learning management integrated with good cha-

racter values. Therefore, the performance of teachers in the implementation of science learning integrated with character education is still less relevant to the planning stage.

In the aspects of learning assessment, the performance of the 52 science teachers in this study is presented in figure 3.



**Figure 3.** Performance of Science Teachers in Semarang City in Planning Science Learning Integrated with Character Education

The performance of 52 junior high school teachers in Semarang City, in terms of the assessment of learning that integrates the character education, 16 people performed very well, 26 performed well, and 10 people performed moderately, while underperformers were not found from the results of this study. Teachers' performance at the assessment stage is done in the form of assignment to evaluate and give reinforcement to the studied materials and also give emphasis on character education that must be instilled in the students. This assessment is also used by teachers to facilitate learners to learn more about materials' substance and the application of materials used to address real-life issues that exist around (Holmqvist, 2011). From here, the instilling process of character education can be really seen by the teacher. Thus, contextual learning assessment can assist in the application of integrated character education in learning.

Science learning management integrated with character education is not an easy matter due to the fact that many students find difficulties in learning science (Hewitt et al., 2007; Marope, 2015). Therefore, the performance of science teachers is increasingly hard to make the difficult ones become easy to understand. On the one hand, integration in science learning becomes an additional task that needs to be paid attention to science teachers in performing ideal teacher

performance. To that end, teachers' performance in science learning management integrated with character education can be improved by guiding the planning process, execution, and assessment. A guiding model that suits the teachers' duties and functions are to use a lesson study model. In this case, teachers' performance can be assisted by other teachers who join the Teachers Training Center at school, city and provincial levels.

Although there is a teacher training system like MGMP, the system has not been fully utilized for various reasons. Thus, the main problem is how to optimize and empower teachers who are members of the teacher forum in the most realistic ways. Prodjosusanto et al. state that there are four principals in reforming MGMP, namely: (1) the development of professionalism should be the point of attention, (2) the frequency of activities should be increased (every two weeks); (3) the type of activity should be more practical and thought-challenging; (4) the system used must be changed from a centralized system into a clump system or region. Furthermore, it provides an alternative solution by using a lesson study framework as an instrument of enabling group work in the MGMP, especially the MGMP schools (Hendayana et al., 2007). Lesson study activities can be used as a model for the development of the educator profession through collaborative and sustainable learning based on the principles

of collectivity and mutual learning to build the learning community (In'am, 2009; Kabassi et al., 2016). In this study, science learning plan integrated with character education is further analyzed to understand whether or not it influences the science teachers' performance in science learning because the problems, like the learning tools, have not been optimally applied in classroom learning.

**Table 2.** Influence of Science Teacher Ability in Developing Learning Tool Integrated with Character Education to the Performance of Learning Implementation

Science Learning integrated with Character	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	T	Sig.
(Constant)	19,32	3,1292		4,458	0,001
Effectiveness of Science Learning integrated with Character	4 0,350	0,067	0,530	4,210	0,001

The result of t test of correlation coefficient showed the t value 4,210 with significance 0,001. Because the significance value is 0,001 < 0,05, it can be concluded that there is an influence of teachers' performance in creating learning tool integrated with character education to its performance in science learning.

## CONCLUSION

Teachers' performance in science learning management integrated with character education in the aspect of developing learning plans, aspects of learning, and aspect of assessment are categorized into the good category. Learning plan integrated with character education has not been fully implemented, meaning that science teachers need to be more consistent between planning and execution. During the research, the study found that target research teachers have been able to include characters in the form of questions used to determine the success of cognitive aspects.

## REFERENCES

- Ahmadi, F., Sutaryono, S., Witanto, Y., & Ratnaningrum, I. (2017). Pengembangan Media Edukasi "Multimedia Indonesian Culture" (MIC) Sebagai Penguatan Pendidikan Karakter Siswa Sekolah Dasar. *Jurnal Penelitian Pendidikan*, 34(2), 127-136.
- Akhwan, M. (2014). Pendidikan Karakter: Konsep dan Implementasinya dalam Pembelajaran di Sekolah/Madrasah. *EL TARBAWI*, 8(1), 61-67.
- Blazar, D., & Kraft, M. A. (2017). Teacher and teaching effects on students' attitudes and behaviors. *Educational Evaluation and Policy Analysis*, 39(1), 146-170.
- Cohen, D. K. (2011). *Teaching and its predicaments*. Harvard University Press.
- Hajar, E. A., & Mukhtar, M. (2017). Evaluation of Teacher Performance Appraisal Program. *Journal of Education Research in Administration and Management (JERAM)*, 1(1), 11-11.
- Hendayana, S., Sukirman, S., & Karim, M. A. (2007). Studi dan Peran IMSTEP dalam Penguatan Program Pendidikan Guru MIPA di Indonesia. *Educationist*, 1(1), 28-38.
- Hewitt, P. G., Lyons, S. A., Suchocki, J. A., & Yeh, J. (2013). *Conceptual Integrated Science: Pearson New International Edition*. Pearson Higher Ed.
- Holmqvist, M. (2011). Teachers' learning in a learning study. *Instructional Science*, 39(4), 497-511.
- In'am, A. (2011). Peningkatan Kualitas Pembelajaran melalui Lesson Study berbasis Metakognisi. *Jurnal Salam*, 12(1), 125-135.
- Judiani, S. (2010). Implementasi Pendidikan Karakter Di Sekolah Dasar Melalui Penguatan Pelaksanaan Kurikulum. *Jurnal Pendidikan dan Kebudayaan*, 16(9), 280-289.
- Julaiha, S. (2014). Implementasi Pendidikan Karakter dalam Pembelajaran. *Dinamika Ilmu: Jurnal Pendidikan*, 14(2), 226-239.
- Kabassi, K., Dragonas, I., Ntouzevits, A., Pomonis, T., Papastathopoulos, G., & Vozaitis, Y. (2016). Evaluating a learning management system for blended learning in Greek higher education. *SpringerPlus*, 5(1), 101.
- Prodjosantoso, A.K., Aznam, N., Arty, I.S., Sugiyarto, K.H., & Yatiman, P.. (2009). Prosiding Seminar Nasional.
- Kartowagiran, B. (2011). Kinerja guru profesional (Guru pasca sertifikasi). *Jurnal Cakrawala Pendidikan*, 3(3), 463-473.
- Khusniati, M. (2012). Pendidikan Karakter Melalui Pembelajaran IPA. *Jurnal Pendidikan IPA Indonesia*, 1(2), 204-210.
- Koballa, T. R., & Chiapetta, E. L. (2010). Science Instruction in The Middle and Secondary Schools.
- Krajcik, J., Codere, S., Dahsah, C., Bayer, R., & Mun, K. (2014). Planning instruction to meet the intent of the Next Generation Science Standards.



- Journal of Science Teacher Education*, 25(2), 157-175.
- Krajcik, J., McNeill, K. L., & Reiser, B. J. (2008). Learning-goals-driven design model: Developing curriculum materials that align with national standards and incorporate project-based pedagogy. *Science Education*, 92(1), 1-32.
- Marope, P. T. M. (2015). Context and participation in curriculum, learning, teaching and assessment.
- Pianta, R. C., & Hamre, B. K. (2009). Conceptualization, measurement, and improvement of classroom processes: Standardized observation can leverage capacity. *Educational researcher*, 38(2), 109-119.
- Saddhono, K., & Rohmadi, M. (2014). A sociolinguistics study on the use of the Javanese language in the learning process in primary schools in Surakarta, Central Java, Indonesia. *International Education Studies*, 7(6), 25.-30
- Sajidan, S., Ashadi, A., & Sutikno, S. (2015). Skill of Teacher Candidates in Integrating The Concept of Science with Local Wisdom. *Jurnal Pendidikan IPA Indonesia*, 4(2), 120-126.
- Sardjijoa & Hapzi. (2017). Integrating Character Building into Mathematics and Science Courses in Elementary School. *International Journal of Environmental & Science Education*, 12(6), 1547-1552.
- Sugiyono. (2012). Metode Penelitian Pendidikan, Pendekatan Kuantitatif, Kualitatif, Research dan Development. Bandung: Alfabeta.
- Zulfikar, T. (2010). The making of Indonesian education: An overview on empowering Indonesian teachers. *Journal of Indonesian Social Sciences and Humanities*, 2(1), 13-39.