

The Use of Computer-Based Interactive Game to Make the Imaginary Logic of Structural Analysis More Real

Anis RAHMAWATI¹ 

¹ Faculty of Teacher Training and Education, Universitas Sebelas Maret, Indonesia

Received: 20.06.2018

Revised: 20.09.18

Accepted: 15.12.2018

The original language of article is English (v.15, n. Special Issue, December 2018, pp.1-12, doi: 10.12973/tused.10251a)

ABSTRACT

This study aimed to design an innovative learning media (i.e., Macromedia Flash program) for Structural Analysis subjects at Secondary Vocational Building Engineering School to improve students' learning outcomes. In the design process, the current study included such stages as definition, design, expert validation, pilot-test, and dissemination. The definition stage formulated subject's achievement indicators or competencies. The design stage included planning a design and then implemented it. Four experts validated the design. The pilot-test gave students a chance to make prior assessments for the designed products. At the dissemination stage, the interactive gaming media was conducted with one class at Vocational Building Engineering School. The results indicated that the developed instructional medias were feasible and effective in improving students' learning outcomes.

Keywords: Computer-based interactive game, learning media, structural analysis

INTRODUCTION

Structural analysis, which is an important subject for civil and building engineers, purposes to contain a proper strength, rigidity, and safety design. This subject consists of different loaded materials and their effects on the buildings. Through a structural analysis process, a comprehensive assessment ensures that deformations occur in a structure due to a maximum load limit in building standards. The structural analysis integrates such disciplines as mechanics, dynamics, and failure theories to compute the internal forces and stresses the designed structures. These integrated disciplines incorporate imaginary logic meaning only descriptions of some conditions instead of real objects. The characteristics of these materials require engineering students to have a kinesthetic learning style (Ictenbas & Eryilmaz, 2011), which enables them to catch the 'structural analysis' concept. The teacher needs more effort and time to help students understand the concept and achieve minimal competencies targeted



by this subject. The successful implementation can be seen as an achievement indicator of the targeted learning, e.g., cognitive learning outcome(s). Some cognitive learning outcomes (e.g.,factual knowledge, cognitive skills, and met²acognitive skills) can be distinguished.

The success of a teaching-learning process depends on some variables, i.e., teachers, students, learning methods and learning medias, and learning facilities. Of these factors, teachers act as a main actor in the learning process and have a crucial role in the success of the learning process. Teachersplan a learning environment and then carry out their plans by arranging learning facilities, and tools and learning strategies. Hence, they facilitate students to grasp the subject's messages easily.

One way to afford students to understand the content of structural analysis the game as a learning tool. Secondary high school students generally enjoy playing games and spend 12.2 hours a week for gaming (Statistica, 2017). The subject matter in a game is more interesting for students. Previous studies have used games in classes and reported their effects on student engagement and cognitive learning outcomes. Further, they have addressed that game playing achieves such varied goals as insights into economic processes, and understanding of a relationship between cause and effect (Huizenga, ten Dam, Voogt, & Admiraal, 2017).

Game, which can be utilized as an interesting learning media, attract students to learn the subject matter with enjoyment. Game, as a learning media, has a capability to make students feel more comfort and fun during the learning process, as well as boosting learning motivation (Fraser, Shane-Simpson, & Asbell-Clarke, 2014; Bjælde et al., 2015; Huizenga et al., 2017). Game-based learning engages students in actively developing their competencies and increases their retention levels of knowledge (Pedersen, Skyum, et al., 2016). Interactive games encourage students to actively involve in every learning process.

Game visualizes the content of imaginary logic in the structural analysis, and promotes them to easily understand. A combination of visual representations and interactive game allows students to obtain an intuition even for materials, which do not have any similarity to their daily life (Lieberoth, Pedersen, & Sherson, 2015). Game-based instruction is an excellent way to provide an authentic context stimulating reality and meaningful learning. To achieve the expected goal(s) of game-based learning, teacher needs to choose the best instructional game and find the right way at the right moment to interact students with each other (Huizenga et al., 2017).

The present study, focuses on a small-scale intervention in a structural analysis course at a secondary vocational school, intends to replaced traditional lectures with game-based learning (a structural analysis game) developed by the teacher and team. The following questions guide the current study: 1) How is the feasibility of an interactive computer-based game for the 'Structural Analysis' course? , 2) At which extent does game-based learningin the 'structural analysis' course make a contribution to enhance students' cognitive learning outcomes?

METHODOLOGY

This study conducted a design-based research (DBR) because it is an ideal research design for developing a game and a new educational technology (Koivisto et al., 2018). A group experts (a researcher, a game developer and a structural analysis' teacher) collaboratively worked and developed an interaction game as a learning media for the 'structural analysis' course at 10th grade in a secondary vocational building engineering school. The DBR followed several steps shown in Figure 1.

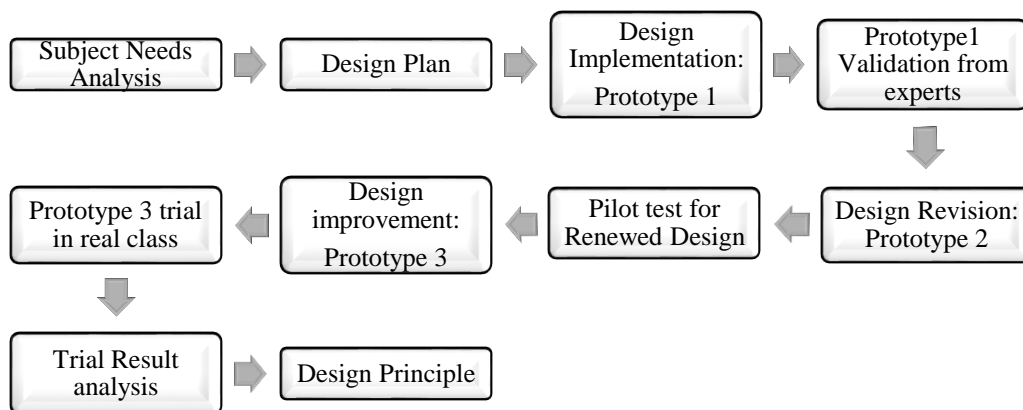


Figure 1. A flowchart for design-based research's steps

In the first step, the research team discussed the needs of subject according to the school's curriculum and its competency indicator(s). Then, team made a design plan consisting of every single material and inserted developed ones into the learning tools. The interactive game was later improved and for the design implementation step, and produced as a prototype 1 of learning media. Four experts (two learning media and two subject matter experts) validated the prototype 1. The prototype 1 was revised given the experts' feedbacks. Hence, prototype 2 was produced and pilot-tested with 10 students. In this process, the students were asked to fulfill a questionnaire about the design of learning media. Data obtained from experts' validation and pilot-test were in two kinds, namely qualitative data in the form of input improvements and quantitative data in the form of scores in the Likert scale. Qualitative data was used as a basis for learning media improvement. Quantitative data scores were then calculated by comparing the score with the maximum score. The percentage score obtained determines the feasibility of the product, with the provisions as in Figure 2 (Riduwan, 2012). Then, based on the results of the pilot-study, the research team made some improvements to generate prototype 3. Later, the improved design was tested in real class with 30 students. Through a pre- and post-test research design, the feasibility of the design was tested.

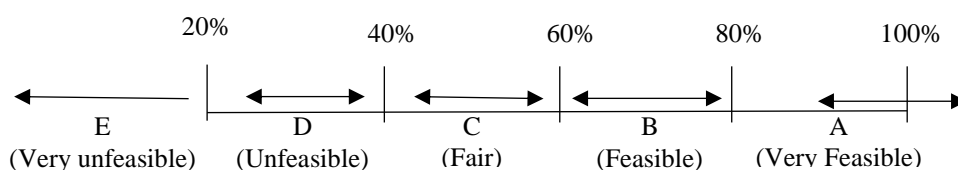


Figure 2. Scale of product feasibility

RESULTS

The results of each step of the design-based research are shown in this section.

a) A need analysis of the subject

Team's members firstly reviewed related curricula and documents (e.g., syllabus, existing learning plan, textbook, and student workbooks). Thereby, they identified the needs for the materials supporting the achievement of the structural analysis competency. That is, this subject

consisted of two main materials, e.g., structure truss analysis including Cremona method, Richter method, Joint method, and Cullman method and mechanics of materials containing stress-strain and deflection. Then, the team observed the existing teaching-learning processes in the school. Their field observations pointed that a printed teaching material was the only available learning tool for theoretical knowledge and questions in student exercises. Unfortunately, students attract less learning interest to the teaching material's writing and performance contents. Given these issues, the team decided that an interactive game would stimulate their learning motivations and create an enjoyable learning environment for the structural analysis subject.

b) Design Plan

For the design plan step, the team created a storyboard or a design sketch that describes the flow of the interactive game learning media. The flowchart of the interactive game learning media created in the design plan is displayed in Figure 3.

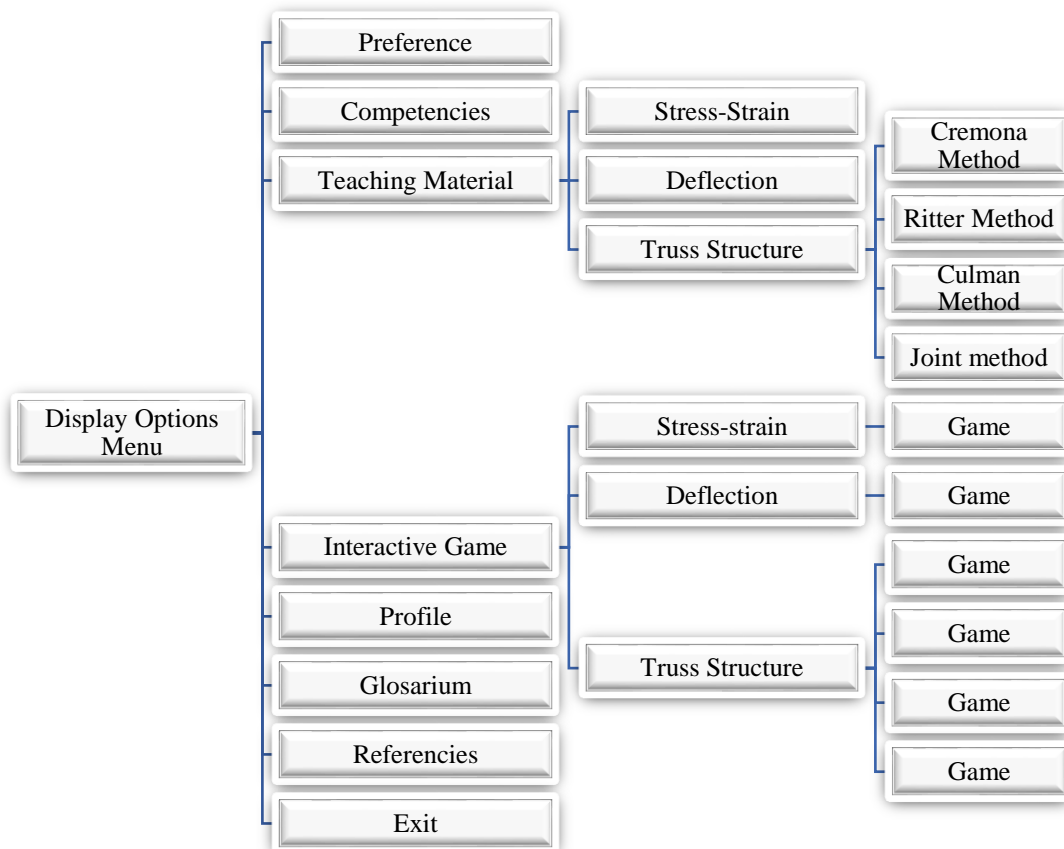


Figure 3. Flowchart of the interactive game learning media created in the design plan

c) Implementation of the Design Plan

This stage aimed to build an interactive game learning media via appropriate softwares that deployed macromedia flash for the learning media, and Photoshop for editing background pictures and media's button. The developers tried to make learning media easily understandable and interesting. The front page of the learning media is displayed in Figure 4.



Figure 4. The front page of the learning media

d) Validating the Learning Media

Four experts (Two subject-matter experts, a civil engineer, a vocational building engineer) checked and validated the prototype 1 of the interactive game learning media. The subject-matter experts focused on its instructional aspects and suggested several revisions/improvements:

- A need to add a 'subject matter' explanation at the beginning of the learning material
- Dividing the subject matter into several parts to facilitate the material search
- Completing all procedures for cremona method in the game.
- Making test questions simpler.
- Addition an interesting animation into the learning material.
- Giving an appreciation after completing each stage of the game.
- Deepening the material, and adding the real structure examples to enable students have a better idea of the discussed constructs.

After revising the prototype 1, the experts scored the revised version of the game by responding a 19-item questionnaire (maximally 95 points -- 5 point per an item) on the instructional aspects of the learning material. The percentage of the subject-matter experts' scores are shown in Figure 5.

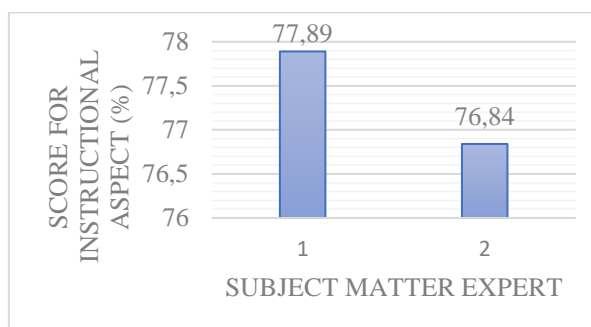


Figure 5. Subject-matter experts' scores for the instructional aspects of the learning material

Two 'learning media' experts (one from an educational quality institution and one from the IT center in Indonesia) reviewed and offered some subsequent revisions:

- Creating a learning media facilitating student understanding of a material by avoiding the use of animation that would threaten student concentration
- A need for consistency in content, terminology and/or display (template)

- c. Using a customizable background sound by considering the type of audio and visual lessons.
- d. Using a backsound fostering students to view the material instead of listening to the songs.
- e. Employing varied assessments methods to measure high-order thinking skills and learning outcomes/competencies.
- f. Ensuring button consistency (home, next, previous)
- g. Illustrating workmanship in the form of the first animation.
- h. Including instructions/manners of the material if required

Based on their suggestions, the team revised the design by improving the ‘button and navigation’ consistencies. Adjusting type of the game to the given problems afforded students to think about problem solving. Media experts responded a 24-item questionnaire (15 for Software Engineering and 9 for Visual Communication -- maximally 120 points). Their judgment scores are presented in Figure 6.

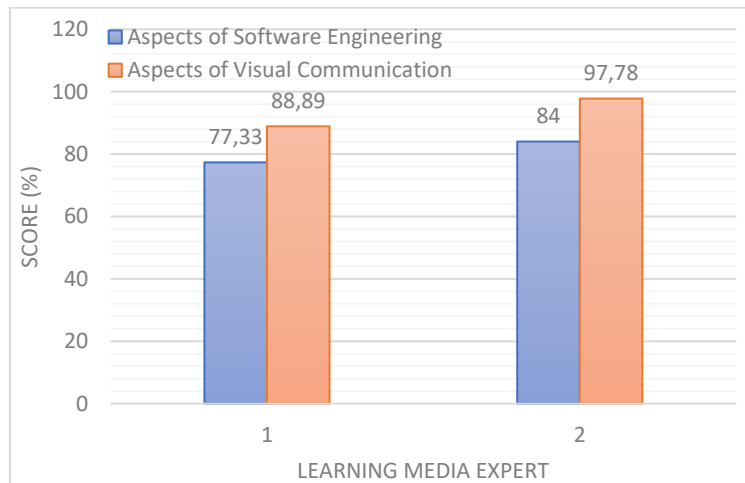


Figure 6. The learning media experts' judgment scores

e) The pilot-test

The last version of the learning media was pilot-tested with 10 students from 10 grade of Building Engineering Department at a secondary vocational engineering school in Indonesia. The pilot-test purposed to get a prior assesment for the designed products. A 31-item questionnaire (14 for the design of the instructional media and 17 for the material conformity) in Likert scale used to gather students' assessment related to the learning media. Besides the closed questionnaire, students give written suggestions for the designed product. The main suggestions appear from the pilot-test were a need for inserting more animations into the media that attracts student's interest and enriching the types of the game to minimize student boring.

The pilot test resulted 561 point for the instructional media, while the material conformity resulted 595 point. The maximal point for both categories was 850. Figure 7 shows the results of the pilot-test in percent. From the results of the pilot test it was concluded that the media developed was in the feasible category.

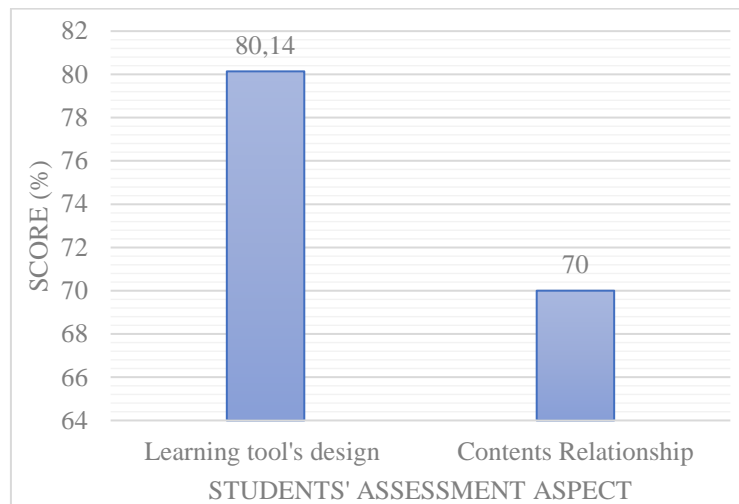


Figure 7. Grade 10 students' assessments of the pilot-test

f) Real study

After revising the learning tool in regard to the pilot-test's results, the revised version was implemented to 30 students from grade 10 in the 'structural analysis' course at a vocational building engineering school. After completing the interactive game learning media, the students were asked to respond a 31-item questionnaire (14 for the design aspects of instructional media and 17 for the material conformity). Their assessment scores are shown in Figure 8. Base on the full class test result it was concluded that the learning tool pointed to a feasibility category (73.9%).

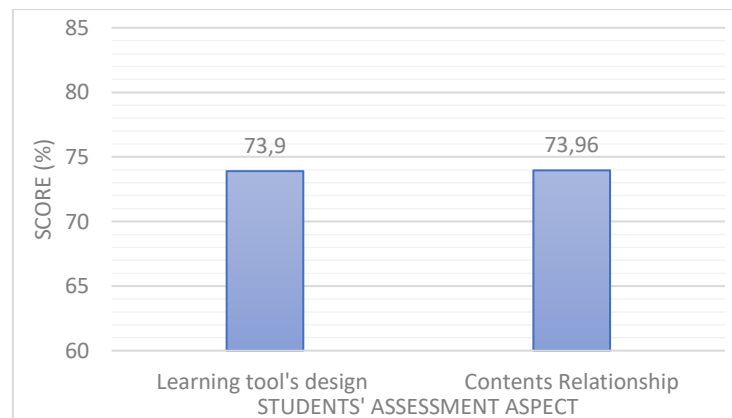


Figure 8. The students' assessment scores after the real study in full class

g) Student's learning outcome(s)

Students' learning outcomes obtained from the pre test and post test with a passing grade of 78. Their learning outcomes in pre-test and post-test is revealed in Figure 9.

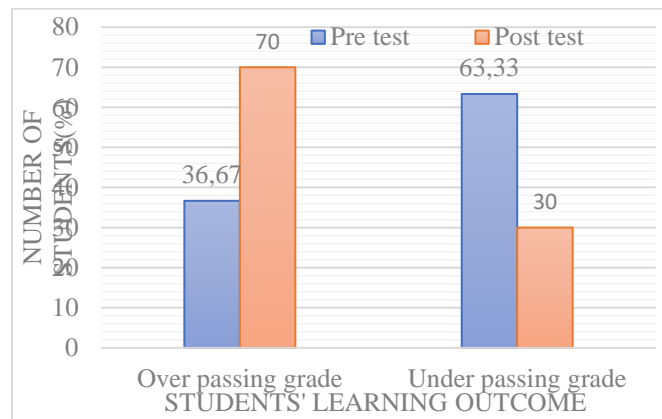


Figure 9. Students' learning outcomes in pre-test and post-test

h) T-Test

T-test was used to measure the extent to which the learning design improved student achievement. That is, t-test compared their learning achievement levels before and after the use of the learning design product. This comparison used the following t-test formula:

$$t = \frac{\mu_1 - \mu_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2} - 2r \left(\frac{S_1}{\sqrt{n_1}}\right) \left(\frac{S_2}{\sqrt{n_2}}\right)}}$$

μ_1 : The average value of the first test (Previous work system)

μ_2 : The average value of the second test (New work system)

S1: First standard deviation (Previous work system)

S2: Second standard deviation (New work system)

r: Correlation between the groups

n1: number of data from the first test (Previous work system)

n2: number of data from the second test (New work system)

Based on the results of the pre- and post-test, the team hypothesized the followings:

Ho = Pre-test was at least equal to post-test

Ha = Pre-test was lower than post-test

Ho = $\mu_1 \geq \mu_2$

Ha = $\mu_1 < \mu_2$

It was the left-side t-test because the alternative hypothesis was "Lower", and t value was:

$$t = \frac{65,33 - 76,03}{\sqrt{\frac{129,56}{30} + \frac{74,23}{30} - 2,0,57 \left(\frac{11,38}{\sqrt{30}}\right) \left(\frac{8,62}{\sqrt{30}}\right)}}$$

$$t = -2,20$$

The foregoing t value, which compared with the distribution of t-test with the degrees of freedom (df) = 29 for the one-party test with 1% error rate, the adjusted t value was 2.462. If the calculated t falls into the acceptance of Ha, Ha states that post-test is better than pre-test. The aforementioned t value (-2.20) accepted Ha or rejected Ho. That is, there was a significant difference between the students' learning outcomes in the pre- and post-test since the post-test value was higher than the pre-test.

DISCUSSION

The imaginary logic of the ‘structural analysis’ subject is more realistic in that the described subject material (Figure 10) was employed animation pictures and several varied types of the interactive games were presented. To cultivate basic understanding of structural analysis, the first game in the learning media was a crossword puzzle game (Figure 11). The crossword puzzle, which appeared in the Sunday New York World in 1913, is an old game (Ntoa, Adami, Prokopiou, Antona, & Stephanidis, 2011). This joyful game has been used in education since 1929 ((Schafer & Behymer, 1992). Constructivist learning theory underpins the use of crossword in learning process. That is, students manipulate learning activities to construct an understanding of new knowledge ((Mergel, 1998).



Figure 10. A sample animation picture



Figure 11. A snapshot for crossword puzzle

The second kind of game (an individual true or false game) on the basic understanding and procedures in the Truss Structure contained the learning media design (Figure 12). The educational true or false game could improve students’ learning motivations (Amalia, 2015). Students’ interests and motivations towards a lesson will enhance their conceptual understanding and trigger their memories (Jumaiyah, 2017).

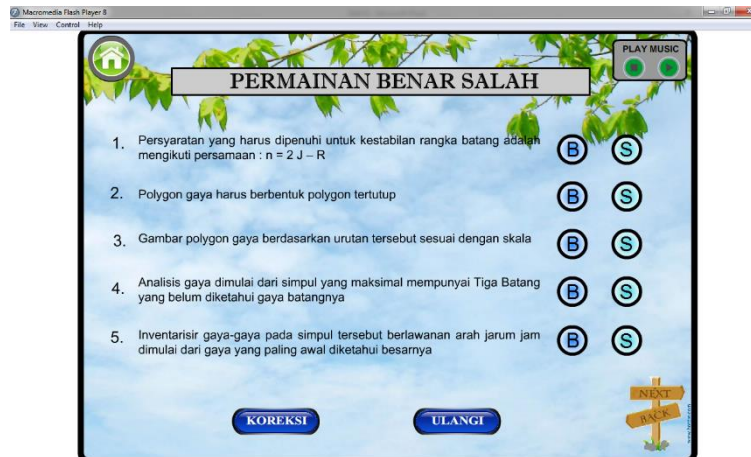


Figure 12. The true or false game

The third type of game (Click and Drag Game—see Figure 13) intended to help students understand the direction of force and solve the truss structure analysis using Cremona method. Students clicked the selected line or direction of the line and then dragged it into the appropriate place on the structure. The Click and Drag game through enactive, iconic, and symbolic representation modes is in a parallel with Bruner's learning theory. In other words, students do the game, see a picture or image, and use some symbols (Bruner, 1966).

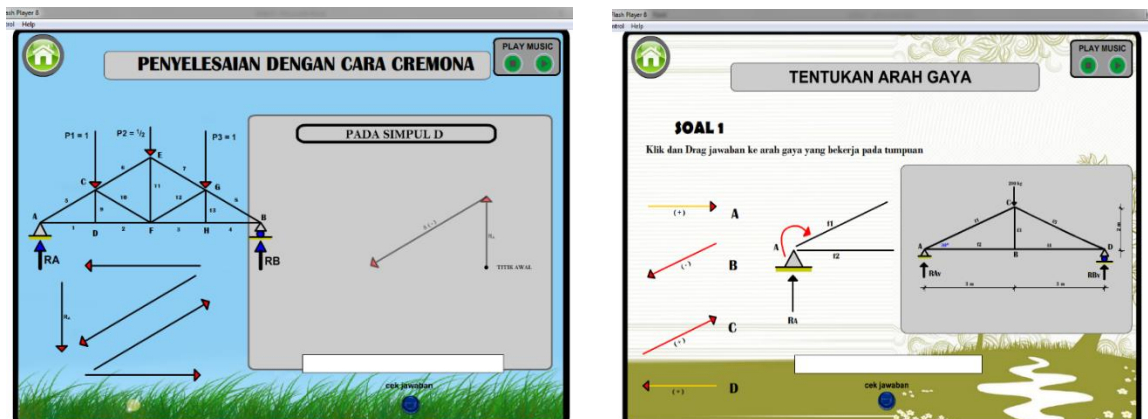


Figure 13. The Click and Drag Game

The team's observations of the design pilot-study and full class test stages indicated that the students were more interested in the game-based IT learning media. The students' learning enthusiasms were activated by the game-based interactive learning media. The results from the real-study showed that this game-based interactive learning media improved the students' learning outcomes. Although they were not at satisfactory level, they at least resulted in better student learning outcomes.

CONCLUSION

In light of the results, the current study reached to the following conclusions:

1. The expert judgments in the presented study states that this game-based interactive learning tool is worthy to be used for the whole class and individual learning.

2. Because the percentages of the student achievement score in the pre- and post-test were 36.67 and 70.00 respectively, it can be deduced that the learning media has a potential to use in classes. As a matter of fact, adjusted t-test value (2.462) supports this knowledge claim.
3. Students could independently operate this interactive learning tool to learn independently. This interactive game does not need to be installed. That is, the program only need to be copied and opened. The interactive game within the learning media makes its appearance and presentation appeal, and helps students comprehend any material change.

REFERENCES

- Amalia, R. (2015). *Penerapan Strategi True Or False Untuk Meningkatkan Motivasi Dan Hasil Belajar Pada Pembelajaran Ipa Siswa Kelas Iv Sd Muhammadiyah 7 Joyosuran Kecamatan Pasar Kliwon Kota Surakarta Tahun Pelajaran 2014/2015*. Thesis. Universitas Muhammadiyah Surakarta.
- Bjælde, O. E., Pedersen, M. K., & Sherson, J. (2015). Gamification of Quantum Mechanics Teaching. Retrieved from <http://arxiv.org/abs/1506.08128>
- Bruner, J. S. (1966). *Studies in cognitive growth: a collaboration at the center of cognitive studies*. New York: Wiley. Retrieved from <https://doi.org/10.1136/bmj.k226>
- Fraser, J., Shane-Simpson, C., & Asbell-Clarke, J. (2014). Youth science identity, science learning, and gaming experiences. *Computers in Human Behavior*, *41*, 523–532. Retrieved from <https://doi.org/10.1016/j.chb.2014.09.048>
- Huizenga, J. C., ten Dam, G. T. M., Voogt, J. M., & Admiraal, W. F. (2017). Teacher perceptions of the value of game-based learning in secondary education. *Computers & Education*, *110*(July 2017), 105–115. Retrieved from <https://doi.org/10.1016/j.compedu.2017.03.008>
- Ictenbas, B. D., & Eryilmaz, H. (2011). Determining learning styles of engineering students to improve the design of a service course. *Procedia - Social and Behavioral Sciences*, *28*, 342–346. Retrieved from <https://doi.org/10.1016/j.sbspro.2011.11.065>
- Jumaiyah, R. (2017). *Penerapan Strategi True Or False Untuk Meningkatkan Pemahaman Materi Sumber Energi Panas Mata Pelajaran Ipa Kelas Ii-B Mi Darun Najah Sidoarjo*. Thesis. UIN Sunan Ampel Surabaya. Retrieved from <http://digilib.uinsby.ac.id/id/eprint/15727>
- Koivisto, J. M., Haavisto, E., Niemi, H., Haho, P., Nylund, S., & Multisilta, J. (2018). Design principles for simulation games for learning clinical reasoning: A design-based research approach. *Nurse Education Today*, *60* (October 2017), 114–120. Retrieved from <https://doi.org/10.1016/j.nedt.2017.10.002>
- Lieberoth, A., Pedersen, M. K., & Sherson, J. F. (2015). Play or Science? A Study of Learning and Framing in Crowdsience. *Well Played*, *4*(1), 30–55. Retrieved from <http://press.etc.cmu.edu/content/volume-4-number-1>
- Mergel, B. (1998). *Instructional design and learning theory. Occasional Paper in Educational Technology*. Retrieved from http://members.iinet.net.au/~aamcarthur/11_March_2008_files/Learning_Theories_of_Instructional_Design.pdf
- Ntoa, S., Adami, I., Prokopiou, G., Antona, M., & Stephanidis, C. (2011). A-cross: An accessible crossword puzzle for visually impaired users. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *6766 LNCS(PART 2)*, 342–351. Retrieved from https://doi.org/10.1007/978-3-642-21663-3_37

- Pedersen, M. K., Skyum, B., Heck, R., Müller, R., Bason, M., Lieberoth, A., & Sherson, J. F. (2016). Virtual learning environment for interactive engagement with advanced quantum mechanics. *Physical Review Physics Education Research*, 12(1), 1–6. Retrieved from <https://doi.org/10.1103/PhysRevPhysEducRes.12.013102>
- Pedersen, M. K., Svenningsen, A., Dohn, N. B., Lieberoth, A., & Sherson, J. (2016). DiffGame: Game-based Mathematics Learning for Physics. *Procedia - Social and Behavioral Sciences*, 228(June), 316–322. Retrieved from <https://doi.org/10.1016/j.sbspro.2016.07.047>
- Riduwan. (2012). *Skala Pengukuran Variabel-Variabel Penelitian*. Bandung: ALFABETA
- Statistica. (2017). Hours children spend gaming weekly in the United Kingdom (UK) from 2013 to 20 by age group (in hours). Retrieved from <https://www.statista.com/statistics/274434/time-spent-gaming-weekly-among-children-in-the-uk-by-age/>

Teachers' Perception on Digital Teaching Material Development in Social Science Education

SARIYATUN¹ , Hermanu JOEBAGIO¹ and Muhammad AKHYAR¹

¹ Faculty of Teacher Training and Education, Universitas Sebelas Maret, Indonesia

Received: 20.06.2018

Revised: 20.09.18

Accepted: 15.12.2018

The original language of article is English (v.15, n. Special Issue, December 2018, pp.13-21, doi: 10.12973/tused.10252a)

ABSTRACT

A form of technology application in learning in the class is digital teaching material development. Social science teachers need to be prepared for mastering technical skills and have pedagogic ability in utilizing digital technology in learning. This study aimed to describe teachers' perception on social science digital teaching material development. Qualitative approach was employed in this study. Case study was conducted in Surakarta City, Indonesia. Data was collected by interview and interview from to explore the respondents' perspectives on the development of social science digital teaching material. The interviewees who agreed to participate in this study were 40 social science teachers at junior high school. The participants were selected with purposive sampling. The teachers were selected according to the criteria of educational background, gender, and experience of scientific activities. Data analysis was carried out using an interactive analysis. The findings of research showed that social science teachers in Surakarta had positive perception on digital teaching material development. The main constraint that the teachers had to encounter was related to time and access to technological equipment.

Keywords: digital teaching material, social science education, teachers' perception

INTRODUCTION

Development of digital teaching materials depend on the fact that social science learning books are not reliable to achieve optimal learning outcomes (Lucas & Passe, 2017; Weng et al, 2018). The most of the teachers feel that existing textbooks are still cognitive, textual and memory-based materials. The content of the books does not cover examples of social skills attitudes such as interacting with others, collaborating and problem-solving skills that can inspire students' cognitive and affective competencies. If there is, it is very limited (Lau et al, 2018).

Social science teaching guidance does not only aim to simply provide knowledge about the facts of social sciences (cognitive) but also to improve students' social skills. Nurturing the social skills of student is one of the responsibilities of social science teachers. Therefore, teachers feel that there is a need for an alternative teaching material which can enable to

achieve social science learning outcomes. On the other hand, the teachers demand an evolution in social sciences teaching (Legare, et al, 2018). In these days, digital teaching materials become solution in learning in the digital era (Dlouha & Pospisilova, 2018). It should be noted that the main effect of the use of digital teaching materials depends on internal factors including the perception of the user (teacher) (Ertmer et al, 2012). A similar study shows that if technology is valuable, it will influence its utilization (Ottenbreit-leftwich et al, 2010).

Related to perception factors of teachers, the use of various technological innovation in the classroom is influenced by environment, regulations, and facility support. The perceptions of teachers play an important role as a first step in the process of successful development of digital teaching materials. If teacher perception is positive, the development of teaching materials will also work well or vice versa. The aim of the research was to detect perception of junior high school teachers about digital teaching material development in social science education.

METHODOLOGY

The research design was a case study of introduction of digital teaching material to the social science teachers at junior high schools in Surakarta, Indonesia. Participants in this study were 47-48 years old. The number of participants were 40 social sciences teachers which were selected according to purposive sampling. Data was collected by interview form. The interview form was developed by considering a conceptual framework that consists of 4 (four) main components of learning process. The first component is included aspects of the ability and performance of teachers. In this aspect, semi-open statements were used to reveal teacher perception on planning for the utilization of digital teaching materials. The second component is to uncover the potential use of digital teaching materials. The third component comprised the pedagogical and technical aspects to reveal the teacher perception on development of teaching materials in relation to the fluency and continuity of teaching and learning activities. The fourth component is about the use of ICT in the social science learning process. Framework of the three principle of data collection, which consist of the use of multiple source of evidence, create a case study database, and maintain a chain of evidence, to construct the validity and reliability of data collection tool and data collection procedure. The interviews conducted with purposive sampling according to educational background.

Data analysis was conducted by using coding and categorization on each of words or phrases in the interview form which were relevant to the purpose of this research. Through the coding and categorization, 32 statements were grouped into 4 (four) main components. Interactive analysis including data collection, data reduction and verification to find common patterns were used as data analysis method in this research. Triangulation of methods by interview and questionnaire. The interview through checking selected with the respective respondents to make sure the data is properly written in accordance with reality was used as data validation technique.

FINDINGS

a) The characteristics of interviewees

There were 40 interviewees at the age of 47 and 48. 47% of the interviewees were men while 53% were women. In terms of education, 45% of the interviewees graduated with Bachelor degree while 55% graduated with Master degree. In terms of experience in following scientific activities, 48% of the interviewees have followed the scientific activities

1-3 times, while 52% of the interviewees claimed that they have followed the scientific activities 4-5 times. The characteristics of the interviewees can be illustrated in Table 1.

Table 1. *The characteristics of respondents*

No	Sex	Total	Percentage (%)	Education		Scientific activities	
				Undergraduate (Bachelor)	Graduate (Masters)	1-3 time	4-5 time
1	Female	21	53	18 (45%)	22 (55%)	19 (48%)	21 (52%)
2	Male	19	47				
Total		40	100	100		100	

From the Table 1, 55% of the teachers had certificate of master's degree in education and had attended in the training of scientific activities as much as 4-5 times. The above teacher profile is an important capital in improving the quality of education.

b) Teachers' Ability and Performance

Almost half of the teachers (45%) stated that they were teaching social sciences for the purpose of developing knowledge and sensitivity to social reality, enabling students to become aware of the reality of a multicultural society. Around 40% of the teachers purposed to improve students' social skills. And only, 15% of the teachers who had a goal just to give knowledge about the facts of social studies to students.

All teachers understand that they have a responsibility to improve student's social skills and instill students' solidarity with nationality. This cannot be separated from the current reality that social skills and national solidarity are fade. Though, social skills are important because it determines the success of student learning while the attitude of national solidarity to form the identity of the student personality. The cultivation of national solidarity is very important to form the knowledge and character of the soul of nationalism, the attitude of patriotism and loyalty to the homeland.

Teachers assess that the process of improving social skills and strengthening national solidarity in social science teaching activities can be performed through the formation of heterogeneous/discussion groups, applying learning models which prioritize cooperation, developing and learning social science materials based on the diversity of local culture.

Teachers also considered that the development of social science teaching materials on the diversity of local cultures would be more interesting, if they are in digital form rather than regular textbooks.

c) The Use of Digital Teaching Materials

The use of digital teaching materials can be seen in the stages of planning, problems, innovation and learning application with digital teaching materials.

Lesson planning: In this aspect, the teachers stated that they (42%) were strongly agree with digital teaching materials are making classes easy to organize, designing and learning will be more structured while as many as 55% agreed, and the remaining 3% were neutral.

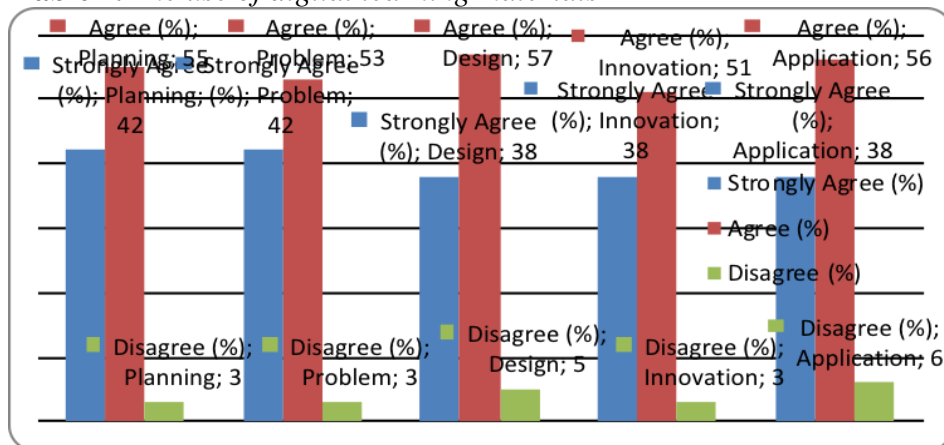
Learning problems: In this aspect, teachers stated that they (42%) were strongly agree with the technology in learning while 53% of the teachers were agreed. While 3% of the teachers disagree with the reason that the use of teaching material is difficult to implemented and takes a lot of time.

Learning innovation: In this aspect, teachers stated that they are strongly agree (38%), agree (51%) and disagree (3%). While the disagreed teachers explained that the use of digital

teaching materials is less efficient in learning and need more adaptation in learning process, method or and learning model to use it.

Learning application: In this aspect, teachers stated that they were strongly agree (38%), agree (56%), and disagree (6%). The teachers agreed that digital teaching materials take time to be developed, but in use they will be more efficient, easier on teaching. In addition, the development of teaching materials is once completed that can be used more than once. But for the teachers who do not agree with the use of technology, they believed that learning innovation and technology application requires professional teachers and a drastic change on understanding, perception, trust and attitude to technology. For more, details are presented in Table 2.

Table 2. The use of digital learning materials



d) Pedagogical and Technical Aspects

The use of digital teaching materials can be considered in the pedagogical aspect of providing new ways to learn, improving the efficiency of learning time, leading to automatic learning, facilitating access to information, and offering collaborative learning. In technical terms, digital teaching materials can be seen as learning tools, information tools and learning content.

Providing a new way to learn: In this aspect, the teachers stated that they were strongly agree (55%) and agree (45%). They agree that the development of digital teaching materials is one of the alternative ways in creating an interesting social science lesson. Using digital-based teaching materials about the diversity of local cultures can create meaningful social science learning for students, provide a wider experience, and can make them more active in learning.

Learning time: In this aspect, the teachers stated that they were strongly agree (50%) and agree (50%). The teachers agreed that the utilization of digital teaching materials in social science learning can improve students' learning efficiency and inspire to learn. In addition, the manufacture of digital teaching materials can improve the effectiveness in the mastery of social science learning materials. Students are more pleased and curious about the content of the presented digital materials, so that they were interest in doing learning tasks.

Cause automated learning: In this aspect, the teachers stated that they were strongly agree (44%), agree (53%), and disagree (3%). The teachers agree that with the support of digital learning materials for social science learning, it will alert students' skills in the decision-making process to solve problems and useful in supporting student self-reliance. As well as with teaching materials/digital textbooks can encourage students to browse the various references.

Facilitating access to information: In this aspect, the teachers stated that they were strongly agree (44%), agree (54%), and disagree (3%). The teachers agreed that digital

teaching materials facilitate teachers in enhancing interactive learning and enable to encourage teachers to apply innovative learning strategies. The digital teaching materials also make students eager to find sources of information. The students easily and more actively access various information as teaching materials.

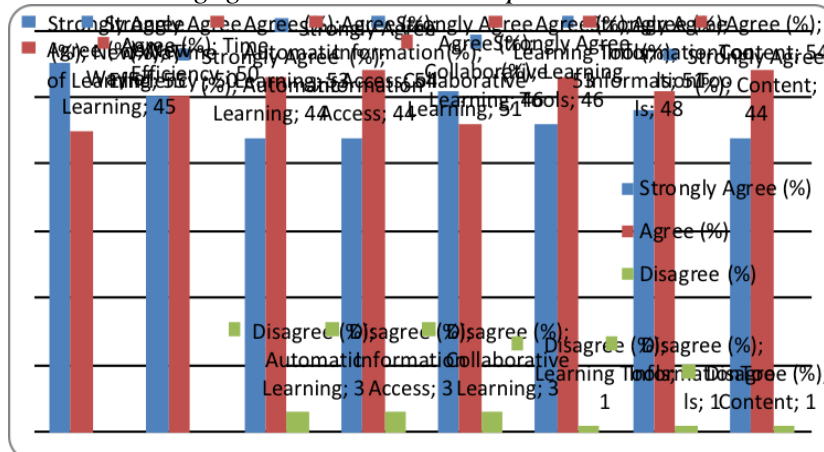
Collaborative learning: In this aspect, the teachers stated that they were strongly agree (51%), agree (46%), and disagree (3%). The teachers agreed that the use of teaching materials/digital books of social science could encourage students to read and learn materials and be social. While teachers who disagreed had reasoned that the use of digital teaching materials of social science only encourage students to be individualistic because the use of digital teaching materials provokes low students' understanding of social attitude. The students were more pleased with their own digital learning tools. As a result, they were anti-social.

Learning tool: In this aspect, the teachers stated that they were strongly agree (46%), agree (53%), and disagree (1%). The teachers agreed that the instructional materials/digital learning social science books based on regional cultural diversity can be used as a medium for discussion. Moreover, it could be used to improve the skills of analyzing, writing and improving skills in social sciences and student's national solidarity. Moreover, the instructional materials/digital learning social science book, which is based on diversity of local culture, could be used to develop learning social sciences.

Information tool: In this aspect, the teachers stated that they were strongly agree (48%), agree (51%), and disagree (1%). The teachers agreed that information would increase with the use of teaching materials/digital books based on regional cultural diversity as a reference for social science learning. And the students' understanding also will increase the ability to synthesize information developed by using digital teaching materials. New information is easier to be obtained with the use of digital teaching materials.

Learning content: In this aspect, the teachers stated that they were strongly agreed (44%), agree (54%), and disagree (1%). They agreed that the use of digital teaching materials made them easier to obtain new information. Applying digital teaching materials required skills and tenacity. It is easy to understand the meaning of social science learning materials in the form of digital books, so easy to be used by students in solving problems. The teachers who did not agree have reason that applying digital teaching materials required complex skills and troublesome, difficult to be applied and understood by students. Age factor becomes the dominant influence. More details presented in Table 3.

Table 3. Pedagogical and technical aspects



e) The Use of ICT in Social Science Learning Process

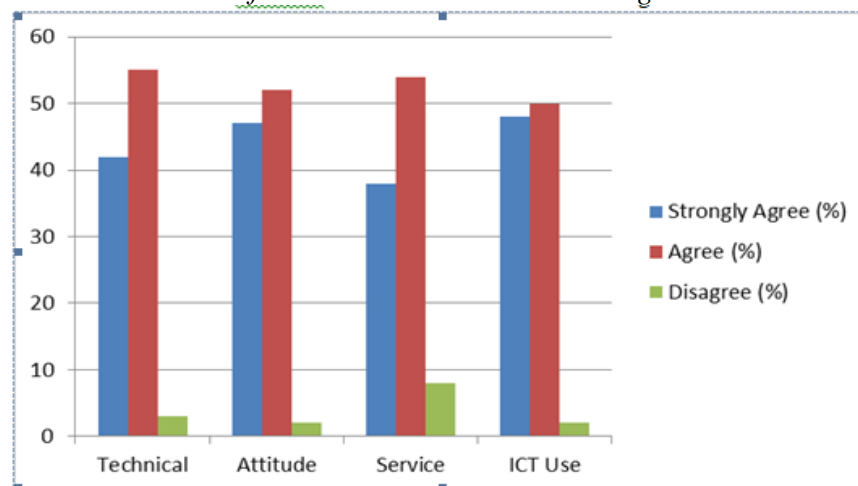
In this aspect, the teachers stated that they were strongly agree (42%), agree (55%), and disagree (3%). The teachers recognized that they were familiar with the technology use at planning, downloading materials, timing and classroom setting to the use of digital books in the curriculum. They considered that digital teaching materials as a technology to support teaching and learning activities more quickly.

Attitudes toward digital teaching materials: In this aspect, the teachers stated that they were strongly agree (47%), agree (52%), and disagree (2%). The teachers, who have Master degree, considered that the digital teaching material were very important as teaching materials. They are attracted as digital resources and useful as a tool for changing learning, accelerating students' understanding, helping students to understand learning concepts, making students more active, and making teachers more confident and enjoying the learning process.

Teacher service in teaching and learning process: In this aspect, teachers stated that they were strongly agree (38%), agree (54%), and disagree (8%). The teachers considered that digital teaching materials did not take time at school. On the other hand, the teachers who disagree explained that the digital teaching materials have less technical support, time constrains, limited software and the minimal availability.

Level of ICT use for teaching and learning by teacher: In this aspect, the teachers stated that they were strongly agree (48%), agree (50%), and disagree (2%). The teacher stated that the were accustomed to use technology for many purposes in learning such as making presentation, preparing teaching, supervising and evaluating students' progress, and generating report. More details presented in Table 4.

Table 4. *The use of ICT in social science learning*



DISCUSSION

The finding of the research has shown that the teachers demands the social science teaching material on the diversity of local culture, particularly in the form of digital books. As Lau (2018) and Osakwe, Dlodlo and Jere's (2017) argumentation, the teachers considered that the digital teaching materials are a technology to support teaching and learning activities more quickly. In line with Ertmer's (2012) finding, the teachers believe that the use of digital technology in learning is the biggest factor for achieving students' learning success.

The teachers agreed that using digital instructional product as an innovation is useful in visualizing themes and making learning more concrete (Mohammadi, Abrizah, Nazari &

Attaran, 2015). In addition, the digital teaching materials are also useful in building more intimately and interwoven interaction with students, making the class more interesting, using the time inefficient, and motivating students to study harder (Sampaio & Almeida, 2016). They are attracted as digital resources and useful as a tool for changing learning, accelerating students' understanding, helping students to understand learning concepts, making students more active, and making teachers more confident and enjoying the learning process (Shieh, 2012; Juan, Sánchez, & Alemán, 2011). Because it is interesting, automatically both teachers and students will be more active in the learning process (Louws et al, 2017).

On the other hand, digital teaching materials become an opportunity as well as challenge for teachers in the digital era. The finding of this research has shown that there is an obstacle in utilizing and developing digital technology in learning (Kim, et al, 2013). The obstacle lies in the on the fact that the older teachers prefer textual materials as usual compared to younger teachers (Bannon & Thomas, 2014). It means the Age factor becomes the decisive factor that affects the application of digital teaching material in social science learning.

Based on the discussion, the authors sum up that the teachers perceive that the digital teaching materials will be more interesting, easier to understand, more practical, less expensive, and more diverse and will be more interesting for students in the digital age. It is supporting Joo, Park and Shin (2017) and Bando's (2017) finding about the good expectation, satisfaction, and continuation of digital textbooks. Thus, as Reyes (2017) pointed out that the teachers' perception of the digital teaching materials can be used as an asset to facilitate teachers in enhancing interactive learning and enable to encourage teachers to apply innovative learning strategies.

CONCLUSION

The teachers considered that the development of social science-based teaching materials for regional cultural diversity would be more interesting if it is given in digital form than regular textbooks. It is because digital teaching materials can be more interesting, easier to understand, more practical, less expensive, and more diverse and be more interesting for students in the digital age Besides, the digital teaching materials are efficient in use. It can also achieve significant learning outcomes with respect to only textbook use. This cannot be separated from the role of the digital teaching materials that are able to visualize the theme and make learning more concrete (real), create meaningful social science learning, able to attract students' attention and interest, and able to improve students' social attitude in digging information and knowledge.

The obstacles faced by most teachers are only about developing the digital teaching materials when the initial planning takes up much of their time. Moreover, most of the teachers are accustomed to use technology for learning, so they have less chance to experience many obstacles. On the other hand, a small number of teachers who are unfamiliar with the technology have more chance to encounter many obstacles in developing it.

REFERENCES

- Al-hunaiyyan, A., Alhajri, R. A., & Al-Sharhan, S. (2018). Perceptions and challenges of mobile learning in Kuwait. *Journal of King Saud University-Computer and Information Sciences*, 279–289.

- Badia, A., & Marta, G. (2016). Exploring the use of educational technology in primary education: teachers' perception of mobile technology learning impacts and applications' use in the classroom. *Computers in Human Behavior*, 21–28.
- Bando, R., Gallego, F., Gertler, P., & Fonseca, D. R. (2017). Books or laptops? the effect of shifting from printed to digital delivery of educational content on learning. *Economics of Education Review*, 162-173.
- Bannon, B. W. O., & Thomas, K. (2014). Teacher perceptions of using mobile phones in the classroom: Age matters! *Computers & Education*, 15–25.
- Dlouha, J., & Pospisilova, M. (2018). Education for sustainable development goals in public debate: the importance of participatory research in reflecting and supporting the consultation process in developing a vision for Czech education. *Journal of Cleaner Production*, 4314-4327.
- Ertmer, P. A., Leftwich, A. T. O, Sadik, O., Sendurur, E., & Sendurur P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, 423–435.
- Joo, Y. J., Park, S., & Shin, E. K. (2017). Students' expectation, satisfaction, and continuance intention to use digital textbooks. *Computers in Human Behavior*, 83-90.
- Juan, J., Sánchez, C., & Alemán, E. C. (2011). Teachers' opinion survey on the use of ICT tools to support attendance-based teaching. *Computers & Education*, 911–915.
- Kim, C., M., Kim, M. K., Lee, C., Spector, M., Meester, K. D. (2013). Teacher beliefs and technology integration. *Teaching and Teacher Education*, 76–85.
- Lau, K. H., Lam, T., Kam, B. H., Nkhoma, M., & Richardson, J. (2018). The role of textbook learning resources in e-learning a taxonomic study. *Computers & Education*, 10-24.
- Legare, C. H., C.H., Opfer, J. E., Busch, J. T. A., & Shtulman, A. (2018). A field guide for teaching evolution in the social sciences. *Evolution and Human Behavior*, 257-268.
- Louws, M. L., Meirink, J. A., Veen, K., & Driel, J. H. (2017). Teachers' self-directed learning and teaching experience: What, how, and why teachers want to learn. *Teaching and Teacher Education*, 171–183.
- Lucas, A. G., & Passe, J., (2017). Are social studies methods textbooks preparing teachers to support students with disabilities in social studies classrooms? *The Journal of Social Studies Research*, 141-153.
- Mohammadi, F., Abrizah, A., Nazari, M., & Attaran, M. (2015). What motivates high school teachers to use web-based learning resources for classroom instruction? An exploratory case study in an Iranian smart school. *Computers in Human Behavior*, 373–381.
- Osakwe, J., Dlodlo, N., & Jere, N. (2017). Where learners' and teachers' perceptions on mobile learning meet: a case of Namibian secondary schools in the Khomas region. *Technology in Society*, 16–30.
- Ottenbreit-leftwich, A. T., Glazewski, K. D., Newby, T. J., & Ertmer, P.A. (2010). Teacher value beliefs associated with using technology: addressing professional and student needs. *Computers & Education*, 1321–1335.
- Reyes, V. C., Reading, C., Doyle, H., & Gregory, S. (2017). Integrating ICT into teacher education programs from a tpack perspective: Exploring perceptions of university


lecturers. *Computers & Education*, 1–19.

Sampaio, D., & Almeida, P. (2016). Pedagogical Strategies for the integration of augmented reality in ICT teaching and learning processes. *Procedia - Procedia Computer Science*, 894–899.

Shieh, R. S. (2012). The impact of Technology-Enabled Active Learning (TEAL) Implementation on Student Learning and Teachers' Teaching in a High School context. *Computers & Education*, 206–214.

Weng, C., Otanga, S., Weng A., & Cox, J. (2018). Effects of interactivity in e-textbooks on 7th graders science learning and cognitive load. *Computers & Education*, 172-184.

The Effect of Picture Storybook Based on Scientific Approach through Inquiry Method toward Student's Inference Skill

Nur ATIKOH¹ , Zuhdan Kun PRASETYO¹

¹ Yogyakarta State University

Received: 20.06.2018

Revised: 20.09.18

Accepted: 15.12.2018

The original language of article is English (v.15, n. Special Issue, December 2018, pp. 22-32, doi: 10.12973/tused.10253a)

ABSTRACT

Many recent studies have reported that picture storybook plays a very important to make a meaningful learning. However, there is lack of the picture storybook that supports the learning process using a scientific approach. Thus, the student's scientific process skill will not develop optimally if the presentation of the material is less interesting and the students are not directly involved in the learning process. This study aimed to examine the difference of students' inference skill after they were taught using picture storybook based on scientific approach through inquiry method and using textbook of curriculum 2013. The used research design was quasi-experiment with the model of pre-test and post-test control group design. The population of research used in this research was grade 5 students of the elementary school in Bantul, Yogyakarta. The sample of research consisted of 47 students. 23 students as experiment class using picture storybook based on scientific approach through inquiry method, whereas 24 students as control class using textbook of curriculum 2013. The result of research showed that there was a significant difference in learning student's inference skill using picture storybook based on scientific approach through inquiry method and using textbook of curriculum 2013. It could be seen from the significance value (Sig.) lower than the significance level (α), ($0,01 < 0,05$). The implication of this research is the learning design will be more creative, innovative, and comprehensive.

Keywords: inference skill; inquiry method; picture storybook; scientific approach.

INTRODUCTION

The process of teaching science in elementary schools emphasizes the provision of direct learning experiences through the use and development of process skills and scientific attitudes (Subali & Mariyam, 2013). Students are expected to have the process skills to investigate the natural surroundings, solve problems, and make decisions by applying scientific process skills. So that student thinking ability can be developed. Therefore, one of the most important things in the success of science learning is the realization of student literacy skills. One of the keys to



realize student literacy skills is improving student inference skills. Meanwhile, inference skills can be used in the science subject (Froschauer, 2013: 27).

The inference skill is essential for students because it includes one of the higher-order thinking skills (HOTS) that must be developed (Kopitski, 2007). Moreover, the inference skill is a powerful way of thinking and an important 21st-century skill for all students to use and develop across the curriculum (Bintz, Moran, Brendt, Ritz, Skilton & Bircher, 2012: 16-24). The inference skill is a popular but nebulous term because it has been defined in many ways. Among others, it has been defined as making predictions, drawing conclusions, using context clues, activating background knowledge, filling gaps, creating interpretations, visualizing meaning, and dealing with ambiguity. These definitions share two important understandings about inference which are “the heart of meaning construction for learners of all ages” (Anderson & Pearson, 1984: 107) and “involving the ability to read between the lines” (Harvey & Goudvis, 2007).

Several studies indicated that inference skills can be improved through organizing learning steps (Rosnawati, 2012), repetition of the material core into the subject, giving questions relevant to the material, making the mapping or the subject matter map (Purnama, 2016) and use of innovative learning methods (Purwaningsih, 2014; Putri, 2016; Utami, Fatmaryanti & Sriyono, 2017). Thus, the student inference skills will not develop optimally if the presentation of the material is less interesting and the students are not directly involved in the learning process (Froschauer, 2013: 27).

In Indonesia, the change of the 2013 Curriculum is one of the constructive efforts to improve the quality of education and teaching. The 2013 Curriculum primarily changes the learning process which is implemented through the application of integrative and scientific thematic approach. The scientific approach to learning adopts the steps of science in building scientific knowledge. Meanwhile, integrative thematic learning is a learning approach that integrates the various competencies from various subjects into lesson themes (Kemendikbud, 2013).

In relation to the implementation of the 2013 Curriculum, teachers are among the stakeholders who are the determinants of the success of every educational effort (Arini, Syahrudin & Sudatha, 2013). Teachers should be sensitive to changes that occur especially in education and teaching. In addition, Anam (2016: 11) argued that one of the keys to the success of the learning process is to position students as an important part of the learning process and invite them to be actively involved in every learning process. Since, the actual learning process has not been optimized that prioritizes student activity, it affects the low learning outcomes of the science subject. In general, low student learning outcomes in the science subject is also reported in many previous studies (Arini, Syahrudin & Sudatha, 2013; Subarjo, Sudhita & Suarjana, 2014; Neka, Marhaeni & Suastra, 2015; Winantara & Jayanta, 2017).

Problems of low student learning outcomes encourage researchers to investigate further into the ongoing learning process. After further investigation, it is found that there are materials that are not in accordance with the concept and there are some errors in the textbook of curriculum 2013. Therefore, it must be addressed by the correction of concepts in order to avoid misconceptions in students. In addition, the distribution of textbooks of curriculum 2013 is often late. As a result, the learning process becomes impeded and the students must be willing to answer the problems in other paper (Krissandi & Rusmawan, 2015).

Another weakness is the time management in the textbook of curriculum 2013 is not balanced (the material does not match the time allocation) (Putri, Jalmo & Marpaung, 2015). The teacher's lack of understanding of the 2013 curriculum also becomes one of the weaknesses (Zulkarnain, Setyowati & Mahanal, 2014). Teachers are not involved in the curriculum

development process. So, teachers are unfamiliar and confused. In practice, some teachers have difficulty in coordinating several lessons on one theme, and teachers find it difficult to understand the learning model offered in the Curriculum 2013. Whereas, textbooks have an important role in the learning process.

Presentation of quality textbooks will greatly assist students in acquiring knowledge and understanding the material (Prihatina, 2016). The field observation results show that the learning resources used in most primary schools are limited to 2013 Curriculum textbooks. In addition, teachers also complained about incomplete 2013 Curriculum textbook materials and very limited book illustrations. Thus, the students are less interested in reading them. The limited illustration impeded the student imagination to understand the taught concepts. Whereas, according to the level of cognitive development, elementary students are in the concrete operational stage (Baharuddin & Wahyuni, 2015:174). This means elementary students are in enormous need of books that feature many pictures.

Empirically, students tend to like picture books that are colorful and contain realistic images or cartoon (Kustiawan, 2016: 32). Through picture storybook based on scientific approach, students are helped to remember the term and understand the meaning in the book by looking at the picture. Moreover, characteristics of scientific approach according to Daryanto (2014: 53) and Hosnan (2014: 36) include: (1) student-centered; (2) involve the skills of the process of science in constructing concepts, laws or principles; (3) involves potential cognitive processes in stimulating the development of the intellect, especially the students' high-order thinking; and (4) can develop student character. This means that learning that applies a scientific approach will encourage students to become active learners, opens opportunities for students to find sources of learning from the environment. Students are accustomed to learn not only by listening, but by using all five senses, and learning is not only seen from the learning but also from activity in the learning process.

The limited textbooks that support the scientific-based learning process and the lack of teacher innovation in designing the learning process have a negative impact on passive students which leads to the low science literacy skills. Empirically, the low science learning outcomes are proven by studies in several years (Arini, Syahrudin & Sudatha, 2013; Subarjo, Sudhita & Suarjana, 2014; Neka, Marhaeni & Suastra, 2015; prasetyo & Prasajo, 2016; Winantara & Jayanta, 2017). Therefore, it needs a supplement book as teaching materials and the application of teaching methods that support the learning process to be more interesting, which is expected to improve students' inference skills. The study aimed to test the effectiveness of a supplement book which was a picture storybook based on a scientific approach with inquiry method. The application of the storybook was expected to improve the students' inference skills.

METHOD

a) Procedure

This study used quasi-experimental methods with a non-equivalent quantitative design of pre-post control group design. The research conducted of two classes, one class as the control class and the other as the experimental class which were selected randomly. The students in both experimental and control classes were given pretest and posttest before and after treatment. At the beginning of the lesson, a set of pre-tests were given to the control and experimental class. The experimental class was taught using picture storybook based on scientific approach

through inquiry method, whereas the control group was taught using Curriculum 2013 textbooks. The design of this research can be seen in below (Table 1):

Table 1. *Design of quasi-experimental research*

Group	Pre-test	Treatment	Post-test
Experimenta I	O ₁	X	O ₂
Control	O ₃	-	O ₄

O₁ : *Pretest* of experimental group, O₂ : *Posttest* of experimental group, O₃ : *Pretest* of control group, O₄ : *Posttest* of control group, X : lesson using picture storybook based on scientific approach through inquiry method, -: lesson using Curriculum 2013 textbooks

The learning of using picture storybook based on scientific approach through inquiry method has several stages in its application. The stages in the inquiry method consist of Engage, Explore, Explain, Elaborate and Evaluate or known as 5E model (Moore, 2015). The summary of implementation picture storybook based on scientific approach through inquiry method is illustrated in Table 2.

Table 2. *Stages of 5E learning model*

Stage	Activity in learning	Implementation in picture storybook
Engage	Students find and identify problems	Read the story and discover the problems of the character encounters through the conversation in the story and the invitation to find out through the activity of “Ayo Amati (Let’s Observe)!”
Explore	Students are directly involved into phenomena and learning resources	The invitation of a character to find answers based on the information presented by the figure through the activity of “Tahukah Kalian (do you Know)?” and “Ayo Cari Tahu (Let’s Find Out)!”
Explain	Students analyze their exploration results by placing the abstract experience into a communicable form	The invitation to cultivate understanding becomes a form that can be communicated through questions about the conceptual understanding through activity of “Aku Tahu (I Know)!” and “Ayo Lakukan (Let’s Do It)!”
Elaborate	Students present the findings or what they understand	A call to express what is understood through activities of “Ayo Simpulkan (Let’s Conclude)!”
Evaluate	The teacher evaluates and determines whether the student has reached an understanding of concepts and knowledge	Presentation of concept comprehension evaluation through activity of “Latihan (Practice)”.

b) Participants

A total of 47 students were involved in this study with 23 students in the experimental group and 24 students in control group. The demographics of the research sample presents in Table 3.

Table 3. *The demographics of the research samples and treatments*

Group	Treatment	Number of Students (N)
Experimental	taught using picture storybook based on scientific approach through inquiry method	23
Control	taught using Curriculum 2013 textbooks	24

c) Data Collection

The technique of collecting data used in this study is testing techniques. The instrument used in data collection is in the form of test description which amounted to 15 questions to measure the student's inference skills. Each question has a range of 0-3. If the students answered correctly and complete, then got score of 3. If the students answered correctly but not complete, then got score of 2. If the student answered wrong, then got score of 1. If the student did not answer at all, then got a score of 0. The value of student inference skills is obtained through percentage of the score obtained by students in answering questions about inference.

d) Data Analysis

The first data analysis performed was descriptive analysis to determine the average value, standard deviation, minimum value, and maximum value. Furthermore, the increase in pretest and posttest results of student's inference skill was analyzed using a gain score. The data analysis technique in this study was ANOVA technique at significance level of 0,05. However, before ANOVA test, the prerequisite test is performed in the form of normality test and homogeneity test. The normality test is used to find out whether the data come from the normally distributed population or not and the homogeneity test is used to determine whether the population of both groups is homogeneous or not.

RESULT

a) Descriptive Analysis

The results of the pre-test and post-test descriptive analysis are shown in Table 4.

Table 4. *The results of descriptive analysis of pretest and posttest on the inference skill*

Description	Experimental Group		Control Group	
	Pretest	Posttest	Pretest	Posttest
The number of the subjects	23	23	24	24
Highest score	66.67	100	73.33	80
Lowest score	26.67	53.33	33.33	40
Average	48.40	72.40	49.67	57.73
Standard Deviation	1.62	2.56	1.61	1.85

b) Improvement of Inference Skill

Data of inference skill from control and experimental class included pretest and posttest data. The increased inference skill of students was shown in gain value from each group and it can be seen on Figure 1.

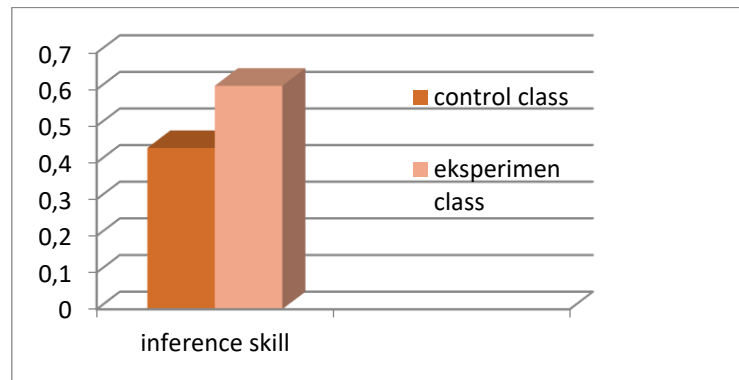


Figure 1. Improvement of the gain value of inference skill

c) Normality and Homogeneity

The univariate assumption tests were performed before the ANOVA test. The univariate assumption tests used in this study were the normality test and homogeneity test. The Kolmogorov-Smirnov normality test was performed on pre-test data of inference skills in experiment and control groups with SPSS 21 program. The results showed that the data were normally distributed or H_0 was accepted with the $\text{sig.} > \alpha$ at the significance level of 0.05. The normality test results are presented in Table 5.

Table 5. The normality test results

Dependent Variable	The Pretest Data of Inference Skill		
	Sig.	Result	Conclusion
Experiment Group	0.289	H_0 is accepted	Normal
Control Group	0.625	H_0 is accepted	Normal

The homogeneity test was performed using Levene's test in SPSS 21. The homogeneity test was performed using Levene's test in SPSS 21. The results show that the data were homogeneous as H_0 is accepted with $> \alpha$ at a 0.05 significance level. The homogeneity test results are presented in Table 6.

Table 6. The homogeneity test results

Dependent Variable	The Pretest Data of Inference Skill		
	Sig.	Result	Conclusion
Inference Skill	0.348	H_0 is accepted	Homogen

d) Influence of Picture Storybook based on Scientific Approach through Inquiry Method to Inference Skill

As the homogeneity test showed that the data were homogeneous, an ANOVA test then could be performed. The results of the ANOVA test on post-test data of inference skills are presented in Table 7.

Table 7. *The result of ANOVA Test*

Dependent Variable	The Posttest Data of Inference Skill	
	Sig.	Conclusion
Inference Skill	0.001	H ₀ is rejected

DISCUSSION

Based on figure 1, the results display that student's inference skill in the experiment group was higher than the control group. This increase was due to the direct student interaction with the picture storybook based on a scientific approach with inquiry method which improved the students' inference skills. Students were motivated to learn since the science learning process was more interactive, and the subject was better understood by the students. It is in line with the opinion of Loh (2016), which stated that the use of picture storybooks creates a relaxed learning environment. Narrative and illustration of picture books reduce cognitive loads. So, the students have a fun of learning process (Hadi, 2013; Kelemen, Emmons, Seston & Ganea, 2014; Loh, 2016). The statement is also supported with Gönen, Durmuşoğlu & Severcan (2009) and Handayani (2010) who explained that picture storybooks enrich a concept and provide students with information.

As present in table 7, it can be concluded that the data for pre-test and post-test between the experiment group and control group also statistically significant difference in inference skill. Thus, a picture storybook based on a scientific approach with inquiry method (which consist of 5E model) affected the inference skill of fifth-grade elementary school students. This is caused by the fact that the student experience is one of the important factors affecting the inference process. This is supported by Kopitski (2007), Froschauer (2013) and Rafferty, Lamar & Griffiths (2012) which stated that the inference process occurs when students combine clues with knowledge that they already have, based on observations of objects or events that have occurred and can also be based on material that students have understood during the learning process. Therefore, the results of this study are highly relevant to the experts' opinions. Kispal (2008) stated that the key to being able to inquire is to read. The picture storybook based on a scientific approach with inquiry method facilitates students to obtain knowledge through reading activities and provide experience through activities existing in the storybook to make an inference based on existing knowledge and experience.

The use of picture storybook based on a scientific approach with inquiry method provides a meaningful student learning experience. This learning experience equips students with the knowledge, which relates to the observed facts or information to form an inference. The study results support the theory proposed by Martin (2012) and Froschauer (2013). According to them, inference skills can be obtained through a series of mechanisms or procedures used to test knowledge in a systematic way that includes answering questions, solving problems, and making a decision in a predetermined object, or it can be said that inference is one of the best explanations for the question "why does something happen?".

The picture storybook based on a scientific approach with inquiry method (which consist of 5E model) answers the challenge because there is a series of scientific approach process, which includes observing, asking, reasoning, trying, and networking in the storybook. In the presentation of the narrative, there are steps of inquiry methods illustrated in each scene.

CONCLUSION

Based on the results of the research and discussion above, it can be concluded that picture storybooks based on scientific approach through inquiry method influenced the inference skills of fifth graders in elementary school. This effect is indicated by a significance of 0.01 (significance <0.05). It means, by using picture storybooks based on scientific approach through inquiry method become more active in the learning process, so that students' science literacy become more honed and student inference skills can be improved.

ACKNOWLEDGMENTS

This research was funded by the DIKTI (Directorate of Higher Education) Ministry of Education, Indonesia through "Hibah Fundamental" Research Grant 2017 for the financial support. Therefore, the researchers would like to thank the DIKTI Institution for the opportunity to obtain the research fund.

REFERENCES

- Anam, K. *Pembelajaran Berbasis Inkuiri Metoda dan Apikasi*. Yogyakarta: Pustaka Pelajar.
- Anderson, R. C., & Pearson, P. D. (1984). *A schematheoretic view of basic processes in reading comprehension (Technical Report No. 306)*. Urbana: Center for the Study of Reading.
- Arini, N. K., Syahrudin, H., & Sudatha, I. G. W. (2013). Pengaruh model pembelajaran addie terhadap keterampilan berpikir kritis dalam pembelajaran IPA siswa kelas V di desa pedawa. *Mimbar PGSD Undiksha*, 1(1).
- Baharuddin, B. & Wahyuni, E.N. (2015). *Teori Belajar & Pembelajaran*. Yogyakarta: Ar-Ruzz Media.
- Bintz, W. P., Moran, P. P., Brendt, R., Ritz, E., Skilton, J. A., & Bircher, L. S. (2012). Using Literature to Teach Inference Accross the Curriculum. *Voice from the Middle*, 20(1), 16-24.
- Froschauer, E. B. L. (2013). *Year Inquiry: A Collection for Elementary Educators*. Virginia: NSTA Press.
- Gönen, M., Durmuşoğlu, M., & Severcan, S. (2009). Examining the views of preschool education teachers on the content, illustrations and physical characteristics of the picture story books used in education. *Procedia-Social and Behavioral Sciences*, 1(1), 753-759.
- Hadi, S. (2013). Pembelajaran Konsep Pecahan Menggunakan Media Komik Dengan Strategi Bermain Peran Pada Siswa SD Kelas IV Semen Gresik. *Jurnal Pendidikan*, 3(4).
- Handayani, S. (2010). Perbandingan Efektifitas Pemberian Informasi Melalui Media Cerita Bergambar (Komik) Versi BKKBN dengan Media Leaflet. *Gaster Jurnal Ilmu Kesehatan*, 7(1), 482-490.
- Harvey, S., & Goudvis, A. (2007). *Strategies that work: Teaching comprehension for understanding and engagement* (2nd ed.). Stenhouse, Portland, ME.
- Kelemen, D., Emmons, N. A., Seston Schillaci, R., & Ganea, P. A. (2014). Young children can be taught basic natural selection using a picture-storybook intervention. *Psychological science*, 25(4), 893-902.
- Kemendikbud. (2013). *Peraturan Menteri pendidikan Nasional dan Kebudayaan RI No 67 Tahun 2013 tentang standar proses*. Jakarta: Kemendikbud.

- Kispal, A. (2008). *Effective Teaching of Inference Skills for Reading*. Literature Review. Research Report DCSF-RR031. National Foundation for Educational Research. The Mere, Upton Park, Sl (2).
- Kopitski, M. (2007). *Exploring the teaching of inference skills*. Doctoral Dissertation, Hamline University.
- Kustiawan, U. (2016). *Pengembangan Media Pembelajaran Anak Usia Dini*. Malang: Gunung Samudra.
- Loh, E. K. (2016). Picture Storybooks in Teaching Chinese as a Second Language. *CLCWeb: Comparative Literature and Culture*, 18(2), 12.
- Martin, D. J. (2012). *Elementary science methods: A constructivist approach*. Cengage Learning. Belmont, CA: Thompson Wadsworth.
- Moore, K. D. (2015). *Effective Instructional Strategies: From Theory to Practice 4th ed*. Los Angeles: SAGE Publications.
- Neka, I. K., Marhaeni, A. N., & Suastra, I. W. (2015). Pengaruh Model Pembelajaran Inkuiri Terbimbing Berbasis Lingkungan Terhadap Keterampilan Berpikir Kreatif dan Penguasaan Konsep IPA Kelas V SD Gugus VIII Kecamatan Abang. *PENDASI: Jurnal Pendidikan Dasar Indonesia*, 5(1).
- Prasetyo, G., Prasajo, L. D., (2016). Pengembangan Adobe Flash pada Pembelajaran Tematik-Integratif berbasis Scientific Approach subtema Indahnya Peninggalan Sejarah. *Jurnal Prima Edukasia*, 4(1) 54-66.
- Prihatina, R. R. N. (2016). Pengembangan Media Pembelajaran Buku Cerita Bergambar untuk Pembelajaran IPS Siswa SMP Kelas VIII. *Social Studies*, 5(8).
- Purnama, F. (2016). Penerapan Model Brain Based Learning (BBL) dalam Pembelajaran Matematika untuk Meningkatkan Kemampuan Berpikir Kreatif Matematis Siswa SMP. *FKIP UNPAS* (2).
- Purwaningsih, S. (2014). *Keterampilan Mengelompokkan dan Keterampilan Inferensi Siswa Pada Materi Redoks Melalui Problem Solving di SMAN 1 Trimurjo*. Thesis, Universitas Lampung.
- Putri, E., Jalmo, T., & Marpaung, R. R. (2015). Kajian Implementasi Pembelajaran IPA Berdasarkan Kurikulum 2013 Kelas IV Sekolah Dasar Negeri. *Jurnal Bioterdidik*, 3(1).
- Putri, D. E. N. (2016). *Penerapan Model Pembelajaran Problem Solving untuk Meningkatkan Keterampilan Keterampilan Inferensi dan Mengkomunikasikan Siswa pada Materi Larutan Penyangga*. Doctoral Dissertation, Universitas Lampung.
- Rafferty, A., Lamar, M., & Griffiths, T. (2012). Inferring Learners Knowledge from Observed Actions. *In Educational Data Mining* (pp. 226-227).
- Rosnawati, R. (2012). Berpikir Kritis melalui Pembelajaran Matematika untuk Mendukung Pembentukan Karakter Siswa. *Prosiding Seminar Nasional Matematika di Universitas Sanata Dharma*, Yogyakarta Indonesia.
- Subali, B., & Mariyam, S. (2013). Pengembangan kreativitas keterampilan proses sains dalam aspek kehidupan organisme pada mata pelajaran IPA SD. *Cakrawala Pendidikan*, 3(3).
- Subarjo, M. D. P., Sudhita, I. W. R., & Suarjana, I. M. (2014). "Pengaruh model CORE terhadap pemahaman konsep IPA siswa kelas V di gugus I NAKULA Kecamatan Negara Kabupaten Jembrana". *Mimbar PGSD Undiksha*, 2(1).
- Utami, I. M. B., Fatmaryanti, S. D., & Sriyono, S. (2017). Efektivitas Model Pembelajaran POGIL Menggunakan Brainstorming untuk Meningkatkan kemampuan Keterampilan Inferensi Logika Siswa. *URECOL*, 161-166.

Winantara, I. D., & Jayanta, I. N. L. (2017). Penerapan Model Pembelajaran TPS Untuk Meningkatkan Hasil Belajar IPA Siswa Kelas V SD No 1 Mengwitani. *Jurnal Ilmiah Sekolah Dasar*, 1(1), 9-19.

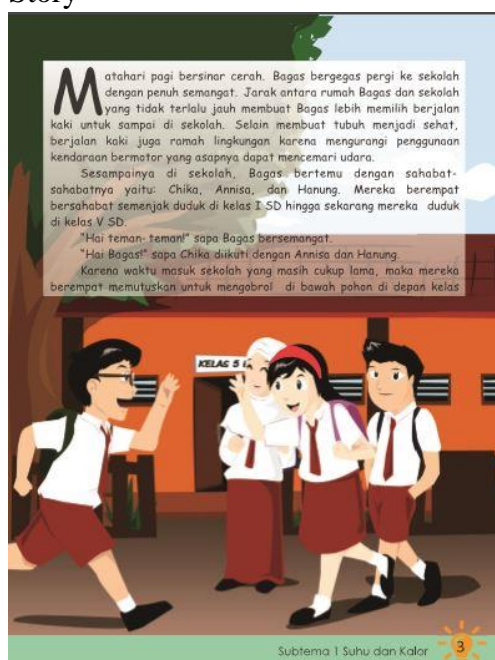
APENDIX

Picture Storybook Based on Scientific Approach through Inquiry Method

1. Cover and introduction of characters



2. Story



3. Steps of Inquiry Method in The Book

Ayo Cari Tahu!

Sumber Energi Panas di Sekitar Kita

Energi panas dapat diperoleh dari berbagai sumber. Untuk memanaskan badanmu yang kedinginan, kamu dapat berjemur. Panas diperoleh dari matahari. Lalu bagaimana air panas di rumahmu diperoleh? Air panas bisa diperoleh dengan cara memanaskannya di atas kompor. Sekarang ini memanaskan air dapat juga dengan menggunakan pemanas listrik "Dispenser". Sumber-sumber energi panas dapat diperoleh dari matahari, api, listrik, juga dari gesekan. Banyak pekerjaan sehari-hari yang memanfaatkan energi panas dari matahari, api, dan listrik. Berikut ini adalah sumber-sumber energi panas yang ada di sekitar kita.

1) Matahari
Pernahkah kamu memperhatikan ketika Ibu mu menjemur pakaian? Ketika dijemur, pakaian terlihat basah. Ketika sore hari, pakaian sudah kering. Ini menunjukkan bahwa matahari memberikan panas pada pakaian. Contoh lainnya, jika kamu berada di bawah terik matahari, kamu tentu akan merasakan panas.



2) Api
Pernahkah kamu berada di sekitar api unggun? Jika ya, tentu kamu akan merasakan panas yang berasal dari api unggun. Ini menunjukkan bahwa api adalah sumber panas. Api sangat bermanfaat bagi kehidupan, diantaranya untuk memasak, menjalankan mesin, membakar logam untuk melelehkannya, dan untuk memusnahkan atau kuman. Namun, kamu harus hati-hati menggunakannya. Api dapat menyebabkan kebakaran. Oleh karena itu, jika sudah tidak diperlukan, sebaiknya api dimatikan.




Subtema 1 Suhu dan Kalor 


Ayo amati!

Untuk lebih memahami suhu dan panas, ayo amati bagian-bagian termometer berikut ini!

Bagian-bagian Termometer



Secara umum, cara kerja Termometer adalah sebagai berikut:
Ketika temperatur naik, cairan pada tabung mengembang lebih banyak daripada gelas yang menutupinya. Hasilnya, benang cairan yang tipis dipaksa ke atas secara kapiler. Sebaliknya, ketika temperatur turun, cairan mengerut dan cairan yang tipis pada tabung bergerak kembali turun. Gerakan ujung cairan tipis yang dinamakan meniscus dibaca

Subtema 1 Suhu dan Kalor 

Ayo Lakukan!

Setelah mengetahui sumber-sumber energi panas yang ada di bumi, ayo buat percobaan kecil untuk menguji gesekan dapat menimbulkan panas!

Untuk membuktikan timbulnya panas dari gesekan benda.

Tujuan:
Membuktikan timbulnya panas dari gesekan.

Alat dan Bahan:
- Penghapus panan tulis
- papan kayu

Langkah kerja:
Gesekkan bagian kayu dari penghapus pada papan kayu selama kurang lebih dua menit. Lalu, peganglah bagian papan yang digesek.

Apa yang kamu rasakan?
.....

Jelaskan mengapa demikian!
.....

Subtema 1 Suhu dan Kalor 

Ayo Simpulkan!

Hal penting apa saja yang kami dapatkan hari ini? Ayo bantu kami untuk menyimpulkannya.

Setelah selesai menyimpulkan, bacalah hasil kesimpulan kalian di depan

Subtema 1 Suhu dan Kalor 

The RME Principles on Geometry Learning with Focus of Transformation Reasoning through Exploration on Malay Woven Motif

Febrian FEBRIAN¹ , Puji ASTUTI¹

¹ Universitas Maritim Raja Ali Haji, Kepulauan Riau, Indonesia

Received: 20.06.2018

Revised: 20.09.18

Accepted: 15.12.2018

The original language of article is English (v.15, n.Special Issue, December 2018, pp. 33-41, doi: 10.12973/tused.10254a)

ABSTRACT

The use of concrete objects in a real-life situation is one of the effective ways for teachers to teach and students to explore and learn transformation geometry. The present study, which used a local wisdom or learning context (called Malay woven motif of Kepulauan Riau), focused on developing the reasoning of transformation geometry with Realistic Mathematics Education (RME) approach. The sample of this two cycles of design research consisted of grade 4 students from a state elementary school of 001 Toapaya, Bintan Regency. The questions ‘How does this learning approach illustrate some characteristics?’ and ‘How well does it perform?’ need to be responded. Hence, the RME principles (i.e., activity, reality, level, intertwinement, interactivity, and¹ guidance) in the implementation of learning have been re-formulated over the years. This study showed that learning geometry through transformation reasoning with all RME principles helped students actively learn mathematics. The context of Malay woven motif brings real and meaningful problems for students to enable the process of mathematization. The learned mathematical content intertwined with other mathematical contents allows learning process to emphasize individual, social, and teacher guide activities.

Keywords: Malay woven motif, reasoning, RME principle, transformation geometry

INTRODUCTION

Geometry, which is limited to two dimensions, is called plane geometry. One of the concepts in plane geometry is transformation, which maps a geometry object on a plane from one position to another with certain rules (Hardiyanti, 2015). The mapping character emerges two types of the transformation, i.e., isometric and nonisometric. Stillwell (2004) states that the isometric transformation of an object from one location to another shows a distance between two points



on the object. Hence, the size of the object will be the same before and after the transformation. This study focused on the geometry of isometric transformations (e.g., reflection, translation, and rotation).

Due to its dynamic nature, transformation is considered as a crucial knowledge in geometry. Understanding transformation geometry includes spatial ability, geometric reasoning, and mathematical proof (Edwards, 1997). At least, this explains the reason why the school mathematics or mathematics curriculum contains the transformation geometry. The National Council of Teachers of Mathematics (NCTM) (2000) states that learning transformation geometry should be taught from kindergarten to high school level, so that students are able to use the transformation geometry to analyze mathematical situations. This is in line with the experts' views suggesting that learning transformation geometry provides an opportunity for students to explore such mathematical concepts as symmetry, congruence, functionality, equivalence and so forth. Further, the transformation geometry involves diverse disciplines in the development of reasoning (Hollebrands, 2003; Panorkou, Maloney, Confrey, & Platt, 2014). Reasoning, which means decision-making and a logical process, is related to the transformation geometry (Febrian & Perdana, 2018). For this reason, reasoning is on the focus of this study.

Referring to the KTSP and the 2013 curriculum in Indonesia, the geometry, especially transformation, is firstly introduced to grade 3 and 4 students. However, teaching transformation geometry with knowledge transfer method makes its effectiveness weak (Febrian & Perdana, 2017). In addition, a lack of the use of concrete objects makes this topic abstract for students and results in reasoning weaknesses.

Conducting a new study on the material of transformation geometry supports reasoning ability. This research used the Indonesian version of Realistic Mathematics Education (RME) approach to set learning. The RME is a domain-specific instructional theory handling mathematics as a subject, children's mathematics learning and how to teach mathematics (Van den Heuvel-Panhuizen, 1996). Although "realistics" in this approach means "real-world" situations in the RME, the word itself has a broader meaning. It depicts the problem that students can imagine (Van den Heuvel-Panhuizen & Drijvers, 2014). Basically, the RME stresses an ideal mathematics learning by doing the mathematics itself. Freudenthal sees mathematics as a human activity. In the learning process, students are expected to re-discover the studied mathematical concepts. Thus, the emphasis in this learning is the process.

RME, as a learning approach, has several principles reformulated by Treffers (Van den Heuvel-Panhuizen & Drijvers, 2014; Van den Heuvel-Panhuizen & Wijers, 2005): (1) activity principle emphasizing that mathematics is learned by doing mathematics itself or known as mathematization to develop concepts and mathematical understanding; (2) reality principle assuming that reality is not only discovered after studying mathematics in solving everyday problems, but also considered as a learning resource and context; (3) level principle explaining that students go through different levels of understanding when learning mathematics in context-related solutions to find related concepts and strategies; (4) intertwinement principle having the meaning that content domains in mathematics cannot be perceived as stands, but are interconnected with each other; (5) interaction principle explaining that learning mathematics is not merely individual activity but also social activity through interaction mechanism during learning; and (6) guidance principle emphasizing teacher's active participation in creating student learning and learning programs to achieve understanding.

Finally, Khusniati, Parmin, and Sudarmin (2017) state that a meaningful and contextual observation arises from student's immediate environment, especially a cultural and local wisdom content. In this point of view, this research used Malay woven motif of Kepulaun Riau as an object to explore and learn. The use of this object may facilitate children's natural spatial senses. The selected Malay motif is called *itik pulang petang*. In this study, students learned the arrangement of *itik pulang petang* in the assignments to build their transformation geometric

reasoning with the RME approach. There are two approaches to understanding the transformation geometry, namely graphical and algebraic ones (Mashingaidze, 2012). This study, which had a focus on graphical reasoning, presented a discussion of the RME principles of in learning transformation geometry reasoning through the exploration of woven Malay motif of Kepulauan Riau, Indonesia.

METHOD

The general objective of this research was to facilitate the development of geometrical reasoning of students' isometric transformation through the exploration of Malay woven motif of Kepulauan Riau. The subject is introduced to grader 4 students at the state elementary school of 001 Toapaya, Bintan Regency, Kepulauan Riau. For this purpose, a design research approach was used: preparing for the experiment; the design experiment; and retrospective analysis. The study consisted of two cycles: preliminary teaching experiment/pilot study (cycle I) with a small-student group and teaching experiment (cycle II) with one class. This paper only provided the results of teaching experiments on the Malay woven motif. The RME principles in the lesson was carried out and presented in this paper. The questions 'How were the RME principles conducted?' and 'How well did the learning perform?' were then open for data analysis. These aspects were critically appraised in the current study.

In preparation of cycle II, hypothetical learning trajectory (HLT) or learning trajectory consisted of: learning objectives, mathematical activities, and conjectured student thinking processes. The presented HLT was updated after the implementation of the first cycle. The HLT for the second cycle of the research is presented in the 'results and discussion' section.





The learning activities were based on the Indonesian version of Realistic Mathematics Education (RME) approach by using the context of Malay woven motifs of *itik pulang petang*. Subjects in the teaching experiment cycle were at grade 4A. The collected data included activity data and student learning, as well as their thinking processes through observation techniques. That is, video recorders and interview techniques were used to explore their thinking abilities. The next data were a series of the student assignments. All data made the current study possible to respond critical appraise on how the RME principles took stand in the learning process and how well the learning performed.

To facilitate the researchers to do a retrospective analysis, all collected data were analyzed by triangulation technique. Segments in videos depicting the students' thinking processes through interviews or discussions were expressed in conversational transcripts and presented in the results. Descriptive qualitative techniques were employed to provide the RME principles in learning transformation geometry reasoning using the context of Malay woven motif of Kepulauan Riau.

RESULTS AND DISCUSSION

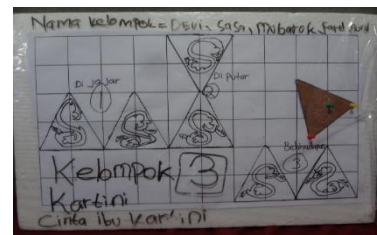
The learning design (consisting of five activities) with the Malay woven motif emphasized on the reasoning of the transformation geometry. Prior to the outcomes and discussions related to the RME principles, the HLT for learning cycle 2 is presented to illustrate its implementation.

Table 1. HLT for learning cycle 2

Mathematical Activities	Tasks	Conjecture of Students' Thinking	A Snapshot of the Activity
Reasoning about the arrangement difference in the motifs of the three varied patterns (Activity 1)	Students observe three varied arrangements of the motif displayed in the gallery-- 'reflection, rotation, and translation' techniques. Students report the result(s) in written and verbal expressions	<ul style="list-style-type: none"> • Students produce informal knowledge such as unit repetition and isometric through object size • Students produce informal terms of transformation based on their observations and comparative activities • Summarizes the differences between the three varied motif arrangements from the technique. 	
With the informal knowledge of activity 1, the students predict and draw the transformation arrangement using a piece of motif as the unit (Activity 2-3)	The activity is called " <i>with a piece of motif, let's think about the drawing technique</i> ". Students are asked to remember the arrangements of three varied motifs. The three variations are retained. The students are asked to play the weaving maker, write a strategy to make variations in the worksheet, and re-create the variation arrangement process. Students are given one piece of <i>itik pulang petang</i> .	<ul style="list-style-type: none"> • Students review visual reasoning of the motif arrangement by producing informal knowledge of transformation • Students predict the technique on making varied motifs by help of one motif • Students perform a hands-on activity on a piece of the motif by moving, rotating, shifting, reversing to adjust the forms of variations in the remembered arrangement • The idea of a constant factor in translation and rotation 	 
Moving motifs on grid media with certain transformations	Students are asked to use the grid media to transform the motif in a triangle	<ul style="list-style-type: none"> • Using the grid to facilitate the transformation • Using certain points and lines as a reference for transformation 	

Investigating the point and orientation of motif image if a particular transformation is made	Students investigate point location and motif orientation that are undergone a certain transformation	<ul style="list-style-type: none"> • Reasoning to use a reference point to find the positions of other points • Using points and lines in determining transformation types • Revealing the image(s) as the result(s) of one or more times of a particular transformation (a combination of transformations)
(Activity 4 a & b)	Students are asked to find the type of transformation if its image is given.	

Exploring the translations, rotations, and reflections on the grid vis-à-vis a motif	Students are required to use the grid and piece of motif to explore transformations by using via their own creativities	<ul style="list-style-type: none"> • Students use grids for transformation media • Students think about orientation, reference point, constant factor in describing transformation object
(Activity 5)		



Furthermore, the HLT had been designed before the implementation of learning in the second cycle was compared to the actual learning path (ALT). Results appeared no difference between the HLT and ALT. In this study, students showed all mathematical activities and thinking processes hypothesized by the researchers. The analysis and discussion of the RME principles in learning transformation geometry through Malay woven motif of Kepulauan Riau are presented as follows:

a) Activity Principle

Activity 1

The purpose of learning in the first activity was to reason visually about the concept of reflection, translation, and rotation and their characters through observation on variations of motif patterns. The Malay woven gallery (as the context) showed three different patterns of a single motif of itik pulang petang. The variations were arranged with 'translation, reflection, and rotation' techniques. Through the observation of differences in the three pattern variations, the students were asked to report the result(s) in written and verbal expressions. In this activity, the students tried to make sense the arrangement of motif in each variation. The students produced informal knowledge connected to the ideas of unit repetition and constant unit size. Through this idea, students built the informal kind of isometrical transformation geometry.

In view of Febrian and Perdana (2018), some informal terms representing translations, e.g., 'arranged in a row', 'slided/shifted', and 'arranged in March,' appeared during the learning process. Further, the informal terms describing reflections were 'made opposite', 'opposite direction', and 'pairing'. Rotation was represented by the phrase 'rotated', 'made circular', 'rounded', and 'around'. The arrangement setting and sequencing of the pattern variation made the students visually aware of the differences in the single motif arrangement in each variation. Hence, activity 1 purposed to persuade the students about the unit repetition and transformations at the informal level.

Through the first activity, the students were engaged in analyzing the situation set within the task. They actively participated in making sense the arrangement differences observable. Overall, the students developed some insights to understand the case, which would be used for the next tasks.

Activity 2

In this activity called "*with a piece of motif, let's think about the drawing technique*", students were asked to remember the motif arrangement in variations of patterns 1, 2, and 3. The display of the variation of the pattern was retained. The students were asked to fill in the sheet to predict the 'making pattern variation' technique for the single motif of *itik pulang petang*.

In view of Febrian and Perdana (2018), some of the students' responses included the variation of pattern 1 by shifting a piece of motif continuously in a certain direction and repeatedly several lines. The students were unaware of the constant factor in shifting. Meantime, the question for the variation of pattern 2 was responded more tactfully. The students generally explored a piece of the motif by rotating it to its midpoint; reversed and shifted. They did it to force the motif to be opposite. The student decided to make a pair of motif facing each other. One of the drawings was made by reversing the motif. The students did a tracing technique in motif propagation to build variations. Meanwhile, the 3rd pattern variation was formed by rotating a piece of the motif. However, they were unaware of the rotary axis or rotation reference point in the process. Activity 3 was continued with the same context.

It can be concluded that the students developed their own ways to understand the arrangement of the motif. However, reasoning in this activity was more observable in 'action' way instead of verbal one.

Activity 3

To follow-up the second activity, the third activity was carried out. The students played an artisan role and went back to the artisan process to come up with three motif arrangement variations. Students drew a variety of patterns 1, 2, and 3 from a piece of motif provided with grid paper media, pins, threads, and styrofoam, as well as drawing tools such as pens and markers. Febrian and Perdana (2018) entailed such strategies as: reversed object to make symmetrical figure for the idea of different orientation; preserved distance in case of translation; constant factor in rotation turning around the distance and angle in a very informal way of verbal reasoning by using informal terms.

The students approached the task by fully using the single motif to trace back the artisan's arrangement. It is clear that students tried to make sense the situation and worked the problem themselves to finally figure out the answer.

Activity 4

This activity used the context of the aforementioned motif in the printed grid medium. The activity recruited class discussion. There was the motif of *itik pulang petang* in a triangle. The location or position of the motif resulted in its transformations. Printed grid media and pins to put motifs on the media were used. The purpose of this activity was to enable students to recognize transformations as displacements of transformed starting points, line and point of reference, orientation, constant factor, and transformation composition. In the first case, the motif was located in the lower left corner of the printed grid medium. The triangle corner point was marked with different color pins. Then, another pin was located in another area in the printed grid media. The student task needed to find other two point locations in order for dissipating transformation to the motif.

According to Febrian and Perdana (2018), the students could think about finding other two point locations so that the case was transitive. Other students might even indicate that such displacement might occur as more than one shift was made.

The students were asked to define the type of transformation that the motif position in the initial triangle was reversed (see Table 1, activity 4). Some students could find the location of other points, so that they could define their transformation appropriately. It can be concluded that the students understood the lines and points of reference, orientation, constant factor, and transformation composition.

Activity 5

In this activity, the students explored to move the motifs in triangles through translation, reflection, and rotation on the printed grid media. A printed grid media and stationery set handed each group out to conduct exploration. The activity indicated that the students comprehended translations, rotations, and reflection as the form techniques to move the initial object to another position on the printed grid media. From these results, the students also described their understanding of the orientation of transformed objects, reference points, and isometric transformation geometry.

From all activities, it can be deduced that the students actively participated in making sense the case within the activity. They used their informal ways to tackle the problem-solving strategy. That is, this learning design promoted the first principle of the RME in a very supportive way. Further, they actively took part in the educational process, and developed all mathematical tools and insights instead of passive receivers of ready-made mathematics (Van den Heuvel-Panhuizen & Wijers, 2005). In other words, this learning design was effective in promoting the students to do mathematical process while trying to solve the problem.

b) Reality Principle

In the learning design, the students were presented with the context of the Malay woven motif throughout the variations of arrangement provoking discussion between students' various assignments. The observations revealed that the use of the Malay woven motifs enriched the concept of transformation geometry for students, and enabled them to organize the concepts gradually. This started from building initial reasoning about the composition of the motif, unit repetition, various forms of transformation and concepts accompanying such as factor constant, distance, angle, and reference point. The composition through a series of assignments was designed in such a way. The learning experience with the motif led to a meaningful learning process and helped the students to build their own understanding of transformation geometry even at an informal level. Thus, the use of motif (as a context) acted as a realistic learning resource and student perception. Their generated knowledge can also be used for other situations. This learning thus illustrates the attainment of the principle of the reality on the RME.

c) Level Principle

In this learning design, the five activities using woven motif as a learning context facilitated students to develop the transformation geometric reasoning. Early development of informal visual reasoning, which is related to the transformation geometry through the motif approach, used informal terms and observations through the idea of unit repetition. Knowledge derived from observation was used to evolve such important ideas as reference points, constant factors, and the orientation of transformed objects through the reasoning process of the use of the object. At the end of the observation, the students used these reasoning skills to build the transformation reasoning activity over the grid medium. The results showed that the students were very flexible for performing transformations above the grid and determining the elements asked in the assignment.

These results indicated that the learning design improved several understanding levels of various transformation geometries through a series of activities using the Malay woven motif of Kepulauan Riau. Thus, the instructional design illustrates the third principle of the RME.

d) Intertwinement Principle

Observations from the learning process, especially on activities 2 and 3, produced many informal ideas through transformation reasoning. Mathematical activity helped the students to predict how the arrangement of the motif in three variations was formed by the weaving artist. Writing in the worksheet and verbal reasoning during the hands-on activity showed that the students associated the concept of transformation with those of distance in 'translation and rotation,' circumference in 'rotation', angle in 'rotation', and symmetry in 'reflection.' At the next level, transformation was successfully connected to the concept of composition in activities 4 and 5. The students informally produced all attributions and indicated an association process between several interrelated concepts and transformation. Domains in mathematics are not data separated from each other (Van den Heuvel-Panhuizen & Wijers, 2005). Thus, the principle of the intertwinement-related RME is reflected in this lesson.

e) Interaction Principle

The learning design was structured by highlighting the students' aspects as social learners. The observations from the learning activities (from activity 1 to activity 5) illuminated that the students jointly built their gradual understanding through the processes of discussion, questioning, and negotiating other views and reflection. Because the RME consider the learning of mathematics as a social activity (Van den Heuvel-Panhuizen & Wijers, 2005), the learning design accommodates the student interaction and raises the principle of interaction successfully.

f) Guidance Principle

The observations from the learning process denoted that the created interaction was not only between the students, but also between teachers and students. Discussion was dominant for the setting of learning through question and answer techniques. In instructional design, teacher acts as a facilitator to equip the students with the necessary reasoning and conceptual discoveries in transformation geometry. In this activity, the teacher asked a lot of questions to trigger their students' further thinking skills of the reasoning. For example; the teacher asked the questions "What are the possible positions of other two vertices if this motif above the grid is exposed to any transformation or a single vertex is placed in this section?", "What do you need to note for this rotation to produce a similar arrangement with variations of the given motive?" and so on. Hence, these questions were very powerful to lure the students to build their understanding of transformation. Thus, teachers are very dominant in guiding students. This is very much in line with the last RME principle of guidance.

CONCLUSION

This study showed that learning the transformation geometry with reasoning fulfilled all principles of the RME. The learning design enabled the students to actively learn some important concepts of the transformation geometry by doing mathematics. The context of the Malay woven motif brought real and meaningful problems for the students to organize the students' conceptual understanding of the transformation geometry. This study illustrated that mathematical content knowledge through the learning process emphasized individual, social and teacher-guide activities.

REFERENCES

- Edwards, L. D. (1997). Exploring the territory before proof: Student's generalizations in a computer microworld for transformation geometry. *International Journal of Computers for Mathematical Learning*, 2(3), 187–215.
- Febrian, F., & Perdana, S. A. (2017). Memfasilitasi penalaran geometri transformasi siswa melalui eksplorasi motif melayu dengan bantuan grid. *Jurnal Gantang*, 2(2), 157–163.
- Febrian, F., & Perdana, S. A. (2018). Triggering fourth graders' informal knowledge of isometric transformation geometry through the exploration of Malay cloth motif. *Journal of Educational Sciences*, 2(1), 26–36.
- Hardiyanti, U. D. (2015). *Pengembangan bahan ajar matematika berbasis website pada pokok bahasan transformasi geometri kelas XI SMK Negeri 26 Jakarta (Thesis)*, Jakarta State University, Jakarta, Indonesia.
- Hollebrands, K. F. (2003). High school students' understandings of geometric transformations in the context of a technological environment. *The Journal of Mathematical Behavior*, 22(1), 55–72.
- Khusniati, M., Parmin., Sudarmin. (2017). Local wisdom-based science learning model through reconstruction of indigenous science to improve student's conservationist character. *Journal of Turkish Science Education*, 14(3).
- Mashingaidze, S. (2012). The teaching of geometric (isometric) transformations at secondary school level: What approach to use and why?. *Asian Social Science*, 8(15), 197–210.
- Panorkou, N., Maloney, A. P., Confrey, J., & Platt, D. (2014). Developing elementary students' reasoning of geometric transformations through dynamic animation. *Proceedings of the 3rd International Constructionism Conference*, 481–489.
- National Council of Teachers of Mathematics. (2000). *Principles standards for school mathematics*. Reston, VA: The National Council of Teachers of Mathematics.
- Stillwell, J. (2004). *The four pillars of geometry*. United States of America: Springer.
- Van den Heuvel-Panhuizen, M. (1996). *Assessment and realistic mathematics education*. Utrecht: CD-β Press / Freudenthal Institute, Utrecht University.
- Van den Heuvel-Panhuizen, M., & Drijvers, P. (2014). Realistic mathematics education. In S. Lerman (Ed.), *Encyclopedia of mathematics education*, 521–525. Springer, Dordrecht.
- Van den Heuvel-Panhuizen, M., & Wijers, M. (2005). Mathematics standards and curricula in the Netherlands. *ZDM*, 37(4), 287–307.

Adopting Educational Robotics to Enhance Undergraduate Students' Self-Efficacy Levels of Computational Thinking

Feri Ardiana ARISTAWATI¹, Cucuk BUDIYANTO² , Rosihan Ari YUANA³

¹ Universitas Sebelas Maret, Surakarta-INDONESIA,

² Dr., Universitas Sebelas Maret, Surakarta-INDONESIA, ORCID ID: 0000-0001-7288-3605

³ Universitas Sebelas Maret, Surakarta-INDONESIA, ORCID ID: 0000-0001-7311-1105

Received: 20.06.2018

Revised: 20.09.18

Accepted: 15.12.2018

The original language of article is English (v.15, n. Special Issue, December 2018, pp. 42-50. doi: 10.12973/tused.10255a)

ABSTRACT

Computational Thinking (CT) skill, as an essential 21st-century skill, is an important problem-solving and survival abilities in the era of disruption. Universal principles generating a pattern of abstraction develop step-by-step troubleshooting instructions in solving similar problems, perceiving similarities/differences between the patterns, and making a complex problem solvable. The skill could be applied to various engineering fields by emphasising efficiency, accuracy, and capability of problem-solving. Recently, robot enthusiasts in Science, Technology, Engineering and Math (STEM) learning that involves 'assembling, programming and testing' activities, underscore CT skills. This research explores the CT pattern along with participants-developed robotics activities.

Keywords: Computational Thinking Skill, educational robotics, self-efficacy, STEM Learning.

INTRODUCTION

Computational Thinking (CT), which is an important 21st-century skill (Wing, 2006), devotes to the field of computers and almost all related disciplines. These skills, which include the ability to identify universal principles generating abstraction patterns, develop step-by-step troubleshooting instructions in solving the same problem (algorithm thinking), recognising the similarities or differences between patterns, trends, and making data, processes or problems (complex) solvable (decomposition).

Although this topic has been taken a considerable attention recent years, little research and literature have inquired on how to deal with Computational Thinking Skills and how to employ strategies developing those abilities (Brennan and Resnick, 2012). Wings (2011) and Bocconi et al. (2016) only discuss and outline computational thinking, usability, and examples of CT through solving real-world problems. Some have used Scratch for CT, but they have only studied with limited programming and samples (Brennan and Resnick, 2012). A complex CT study with robotics examined how to integrate CT skills into junior and senior



high schools (Atmatzidou and Demetriadis, 2016). The research was an inspiration for robotics learning with constructivism approach at higher education level.

Jean Piaget (1972, cited by Ackermann 2001) states that humans learn not only from the transmission of knowledge but also actively engaging in an activity or experience-based knowledge. Papert (1980) adds that understanding knowledge will be more effective if learners construct their knowledge-related products throughout their own experiences. In Papert's view of constructivism, practical (hands-on) learning uses tangible and intangible objects. Constructivism itself includes learner's active engagement so that (s)he builds an understanding or meaning on what (s)he has done.

Given the 21st-century skills, the researchers proposed robotics learning in designing, constructing, programming, and controlling the tangible objects. Because constructivist learning approach emphasizes a student-centred learning and doing science via guided inquiry activities, some activities, in hand, are intended to provoke computational thinking skills. This research explores the computational thinking pattern along with participants-developed robotics activities. The current study purposes to stimulate the development of computational thinking skills using a constructivist learning approach.

CONCEPTUAL BACKGROUND

Computational Thinking

Computational thinking, which is a problem-solving method commonly used by computer scientists (Eguchi, 2014), advocates the 21st-century skills (Wing, 2006). Computational thinking skill is devoted to mainly the field of computers and almost all related disciplines. This ability pays attention to the utilisation of technology and underlying concept of technology creation.

Peyton Jones (cited in Bocconi et al. 2016) states that computational thinking skill develops patterns of real-world problems as well as designing, developing, refining and explaining how computing technology works. Computational thinking can be developed by integrating it into the compulsory education curriculum. Thus, learners are expected to view the problem from different perspectives, express themselves with various media, and analyse daily problems. Also, developing a CT promotes the future of economic growth, employment in the field of computers and work-preparation (Bocconi et al., 2016).

Educational Robotics

Robotics and automation machines have entered the fields of education and industry. However, the introduction of robotics in education is usually only limited to the technological sophistication of the robot itself (Alimisis, 2012). The robot can be seen as an excellent educational tool to achieve learning. Karim and Mondada (2015) address that modern robotics has been used for such technical and non-technical learning as mathematics, physics, science, language, and music.

Robotics, which is a new learning media to relay knowledge, teaches reality and knowledge to learners (Miglino, Lund, and Cardaci, 1999). Robotics is one of the best learning technologies and media that can integrate knowledge, skills, and attitudes within each other (Miglino et al. 1999). Robotic activities include to design, build, operate, and use robots and computers as control, sensors, and information processing. Robotics is a computational thinking material to meet technological requirements including intelligence and embodiment. Robotics interacts learners with media (Catlin and Woollard, 2014).

Using robotics, which encourage learners to construct their own robots, will introduce new, creative and innovative technologies to learners. Learners will also have a mindset to

become active technology/science creators rather than passive technological consumers (Eguchi, 2014).

Constructivist Learning Theory

Constructivist learning theory proposed by Piaget (1972) underpins robotics inspiration as a learning medium. It is argued that learners interpret the theory very well if they apply it to real-life issues or problems through creation and innovation. A constructivist learning model explores student's knowledge by manipulating and constructing tangible objects. The learning activity enables learners to interpret new knowledge with their pre-existing one. In view of Papert's constructivism theory and Vygotsky's socio-cognition approach, robotics activity makes learners to actively build a piece of new knowledge by collaboratively developing critical mental skills with their peers.

Previous Researches

Table 1 summarises the findings from previous researches.

Table 1. Findings of previous researches

Title	Author	Main Findings
Advancing students' computational thinking skills through educational robotics: A study on age and gender relevant differences.	Atmatzidou, S., and Demetriadis, S. (2016)	Male and female students had the same achievement, but female students needed more extended training. Also, the activity increased their compulsory thinking skills.
Robotics in education & education in robotics: Shifting focus from technology to pedagogy	Alimisis, D. (2012)	Teachers felt that they were active in utilising technology and designing the rich technological learning. Junior high school students understood the concepts of informatics and kinematics and felt the pleasure while building a robot.
Robotics as an educational tool	Miglino, Lund, and Cardaci (1999)	The related literature revealed two ways to explore computing thinking skills in educational contexts, such as (a) generate system-based interactive knowledge (i.e., internet services, multimedia encyclopedias, etc.) (b) build a simulation laboratory to gain knowledge by following scientific research method(s) (e.g., formulating and testing hypotheses).
Computational thinking and tinkering: Exploration of an early childhood robotics curriculum	Bers, Flannery, Kazakoff, and Sullivan (2014)	The results showed a high achievement level while assembling the robot. However, the achievement level decreased during programming and rose again on conditional programming.
New frameworks for studying and assessing the development of computational thinking.	Brennan, and Resnick (2012, April)	The 8-16 aged children in the Scratch community were accustomed to use such computational thinking skills as sorting code, understanding the patterns (looping) and thinking about the problem-solving steps.
Robotics as a learning tool for educational transformation.	Eguchi (2014a)	Learning robotics effectively involves students in learning STEM concepts, coding, computational thinking and engineering skills that students will need to work in the future.
Educational robots and computational thinking.	Catlin, and Woollard (2014)	The results of robotics have a strong symbiotic relationship with the 'computational thinking' skill. Robotics is also a practical form of computational thinking.

METHODS

Through a qualitative approach, the current study investigated participants' experiences of educational robotics. The participants experienced robotics activities with LEGO Mindstorm EV3 for its sophisticated visual and interactive programming interface. The LEGO Mindstorm also added the advantages of robotics to constructivist learning theory (Kamal, Budiyo, & Efendi, 2018). Since participants were relatively ancient to modular robotics, the robotics activities began with a brief introduction to LEGO models and modules. Then, they built their robot models using LEGO Mindstorm EV3. During the activities, the researchers simultaneously observed participants' behaviours and conducted semi-structured interviews after all participants completed their sessions.

a) The Sample of the Study

Eight undergraduate students purposefully (Creswell, 2014) drawn from the department of informatics voluntarily participated in the current study. All participants had Informatics Education background and were familiar with programming. As seen in Table 2, they represented four different grades and gender equity. Even though most of them had attended programming courses, they had no previous experience with robotics.

Table 2. Demographic features of the sample of the study

Student	Semester	Gender	Programming Lessons	Robotic Experience
Student A	8th semester	Male	Nine times	No
Student B	8th semester	Female	Eight times	Yes
Student C	6th semester	Male	Ten times	No
Student D	6th semester	Female	Six times	No
Student E	4th semester	Male	Five times	No
Student F	4th semester	Female	Five times	No
Student G	2nd semester	Male	2 times	Yes
Student H	2nd semester	Female	2 times	No

b) Setting

This research initially administered a questionnaire to assess the participants' computational thinking proficiencies. The second part included the implementation of the LEGO Mindstorm EV3 as the robotics activity (i.e., robot assembly, programming, and testing) asking them to build a simple model. While participants engaged in the robotics activities, the authors observed the participants' behaviours and took observation notes. In the third part, the participants were interviewed about their experiences of the robotics activity and progress. The interview protocol and codes were analyzed according to the computational thinking skills (see Table 3).

Table 3. Indicators of the in-depth interview (adopted from Atmatzidou and Demetriadis, 2016, p. 664)

CT Skills	Description	Students' Skills (Students are able to)
Abstraction	Addresses a creating process from simple to complicated by taking out irrelevant details, finding relevant patterns, and separating ideas from concrete details. The essence of CT is an abstraction (Wing, 2008).	<ol style="list-style-type: none"> 1. Separate important information from unnecessary one. 2. Analyze and specify common behaviours or programming structures between different scripts. 3. Identify abstractions between different programming environments.
Generalization	Transfers a problem-solving process to a wide variety of problems	Extend an existing solution in a problem to yield more possibilities/cases.
Algorithm	Practically writes step-by-step specific and explicit instructions for carrying out a process. Selecting appropriate algorithmic	<ol style="list-style-type: none"> 1. Explicitly state the algorithmic steps. 2. Identify different useful algorithms for a given problem.

	techniques is a crucial part of CT (Kazimoglu et al., 2012).	3. Find the most efficient algorithm.
Modularity	Develops autonomous processes that encapsulate a set of common commands performing a specific function. It might be used in the same or different problems	Develop autonomous code sections for the same or different problems.
Decomposition	Breaks down problems into smaller parts that may be more easily solved. CT uses decomposition while attacking or designing a massively complex task (Wing, 2008).	Break down a problem into smaller/simpler parts that are easier to manage.

c) Data Analysis

After data collection, data reduction was conducted to select relevant and meaningful data. Hence, the authors focused on data leading to problem-solving, discovery, meaning or research questions. That is, the findings answering research questions were handled. Data from in-depth interviews and observations were trialed and analyzed using interactive analysis (Miles and Huberman, 1994). The data were presented to describe recent circumstances purposefully. The early phase of the research progressed as a temporal insight and understanding until a theoretical saturation achieved.

RESULTS

The second part of the research contained to elicit the participants' programming-related barriers. Table 4 summarizes the results of the interview protocols.

Table 4. *The Participants' Programming-related-Barriers*

Students	Algorithm	Syntax	Complex Algorithm
Student A		X	
Student B	X		
Student C		X	
Student D			X
Student E	X		
Student F		X	
Student G	X		
Student H			X

The students' programming barriers consisted of Algorithm, Syntax, and Complex Algorithm. The algorithm is defined as the first step to think how the program should be constructed that requires logical thinking. The syntax, which is perceived as the problem to express a new programming language, compiles an algorithm. Finally, the complex algorithm is the activity with merging loops and conditionals.

The student E concerned a need to think about the appropriate algorithm. The students B and G experienced a similar problem. *"I have difficulty thinking about algorithms. (I) need a long time and have to repeat the questions over and over again. (It is frequent that) I am (ended up) asking friends for help."*

Students A, C, and F faced the difficulty to express the appropriate Syntax. The Student A mentioned about a problem a new programming language: *"I can compile an algorithm, but when applying to the code, it sometimes takes time."* Similarly, Student C referred to the following expression: *"Programming is not a difficult thing (to deal with), (to) write the codes that require mastery (in programming)."*

An increase in complex assignment forced their abilities to solve their problems. For example; the student H expressed the following quotation: *"I can only do either conditional or looping. However, when I have to work on a program that requires conditional and looping combinations, I cannot."*

To follow up their responses to the interview protocols, they were asked to conduct robotics learning to find out how they progressed with their CT skills. The results of each CT area are outlined in the following:

a) Abstraction and Modularity

Table 5 summarizes the results of their responses of the ‘abstraction and modularity’ areas.

Table 5. *The participants’ responses of the ‘abstraction and modularity’ areas*

Questions	Their responses to the questions
What is the typical behaviour of the robot?	All students demonstrated that the robot moved forward until it detected an obstacle, then it executed the following command
What is the general programming structure?	All students indicated the first and second programs. That is the robot run and stopped till the sensors detected something, only different in the sensor. The third was a combination of the first and second programs.
Which programming did the students do firstly?	All students, but the students B, D, E, and G built their programs in sequence. The student B, D, E, and G tested their robot models after the first program was done to ensure whether the robot runs correctly. They could do the next programs more accessible after testing.

b) Generalization

Table 6 depicts the results of the participants’ abilities of constructing a generalization.

Table 6. *The participants’ abilities of constructing a generalization*

Questions	Their responses to the questions
Please suggest a more generalized solution to implement sensors covering a wide range of cases.	The student A mentioned line following disability chair, which detected the upcoming obstacles via infrared. The student B mentioned car with traffic light detector and auto brake. The students C and G mentioned line follower for factory vehicle and car with auto brake.
Is the proposed solution more general? Please explain your reason	The student D mentioned auto cleaner with an infrared sensor (without referring to the colour sensor). The student E mentioned fire extinguisher with a light sensor and a stick for visually impaired people using an infrared sensor. The student F mentioned line follower (without referring to the use of an infrared sensor). The student H did not mention anything.

c) Algorithm

The observation and interviews showed that all participants completed to programming, but the student G failed the assignment of algorithm construction. The algorithm phase started by writing down how the motor had to run. Then, they determined when the motor had to turn off. The student G wrote only how the sensor worked and failed to explain the state of the motor. Subsequently, they implemented their algorithms to the block programming (in LEGO Software Home Edition). Table 7 shows how many times they tried to work on programming until the robot’s movements complied with pre-determined objectives.

Table 7. *The number of the participants’ programming attempts*

	SA	SB	SC	SD	SE	SF	SG	SH
Program 1	1	2	1	1	1	1	1	1
Program 2	1	2	1	1	1	1	2	1
Program 3	1	3	3	3	3	2	2	1

d) Decomposition

As can be seen from Table 8, the participants were either grouped all items first (GAF) or grouped per slide (GPS). The participants, who were grouped, were crossed in both categories.

Table 8. *The results of the assembling activity*

Steps	S A	S B	S C	S D	S E	S F	S G	S H
GAF	x	x	v	x	v	x	x	v
GPS	x	x	v	x	v	x	v	v
Step 1	v	v	v	v	v	v	v	v
Step 2	x	x	v	v	x	x	v	x
Step 3	v	v	v	v	v	v	v	v
Step 4	x	v	v	v	x	x	v	v
Step 5	v	v	x	v	x	v	x	v
Step 6	v	x	v	v	v	v	v	v
Step 7	x	x	v	v	x	x	x	x
Step 8	v	v	v	v	v	x	v	v
Step 9	v	v	v	v	v	v	v	x
Duration (Minutes)	50	58	24	37	29	40	43	37

When the student G was inquired about his choice of grouping, he selected the components required in each step. He spent 43 minutes for all steps in the assembling activity. The students C, E, and H, in contrast, grouped all components before started to assembling. The rest of the participants directly built their robots without sorting the components out.

DISCUSSION

The research evaluates the effectiveness of educational robotics to endorse undergraduate students' computational thinking. The participants with basic programming knowledge addressed that they had difficulties in algorithm, syntax, and sophisticated algorithm. The participants pointed to their inclination levels towards each area of Computational Thinking in the robotics activities. This research handled the Computational Thinking with five competencies comprising of Abstraction, Modularity, Generalization, Algorithm, and Decomposition (Atmazidou & Demetriadis, 2016). In light of the results, the participants indicated a self-efficacy transformation along the treatment.

a) Abstraction and Modularity

The participants, who demonstrated their CT skills in the area of abstraction and modularity, explained how their robots were structured. That is, LEGO Mindstorm helped them identify and classify the functions of the program and simply ignoring unnecessary details (Weese & Feldhausen, 2017). They further elaborated on how a particular component of the robot responded to the instructions implemented in the program.

b) Generalization

The ability to identify a particular component in the robotics module and associate it in another context seems to well-conveyed in the data analysis. Transferring a solution into a broader context is regarded as a mental construct associated with the Computational Thinking skill (Atmatzidou & Demetriadis, 2014). The participants were asked to mention their devices related to colour and infrared sensors. Hence, they were invited to probe how to associate the devices with the real world.

c) Algorithm

The participants were asked to express their algorithm proficiencies through written responses and projects in LEGO Mindstorm Home Edition software. Although some of the participants repeatedly worked their solutions out due to an increase in the problems' complexities, they enjoyed learning robotics. The block programming facilitated to identify either a single step or multiple steps in a solution. The use of loops underscored the usability of repeated commands (Weese & Feldhausen, 2017) as visually depicted in the interface.

d) Decomposition

Decomposition, which is the ability to break down a complex problem into small parts, makes a complex problem easily solvable. The modular part of LEGO Mindstorm engaged the participants in assembly and disassembly activities. Grouping or ungrouping the components is considered as the simulation breaking complex problems into a solvable smaller situation. The problem-solving strategy, however, would be affected by individual learning behavior (Kamal, Budiyanto, & Efendi, 2018).

CONCLUSION

This research evaluated how the participants developed their computational thinking skills while dealing with robotics learning. It is evident that the participants demonstrated varied computational thinking skills. Each participant tended to craft specialized proficiency levels of computational thinking skills in different areas. The robotics-assisted learning, in this regard, enabled the participants to explore and develop their CT skills. A long-term robotics activity, however, is required since some participants needed a longer time to explore their particular components. Given their interactions with educational robotics in a short-duration, the participants sufficiently comprehended the essence of the robotics learning and managed robotics- and computational thinking-related knowledge. Indeed, because the participants obtained pre-existing knowledge in computational thinking and managed their computational thinking skills, they may have tackled the robotics learning efficiently.

REFERENCES

- Ackermann, E. (2001). Piaget's constructivism, Papert's constructionism: What's the difference. *Future of learning group publication*, 5(3), 1-11.
- Alimisis, D., Arlegui, J., Fava, N., Frangou, S., Ionita, S., Menegatti, E., ... Pina, A. (2010). Introducing robotics to teachers and schools: experiences from the TERECOP project. *Proceedings for Constructionism*, 1, 1-10.
- Alimisis, D. (2012). Robotics in education & education in robotics: Shifting focus from technology to pedagogy. In *Proceedings of the 3rd International Conference on Robotics in Education*, 7-14.
- Alimisis, D., Moro, M., Arlegui, J., Pina, A., Frangou, S., & Papanikolaou, K. (2007, August). Robotics & constructivism in education: The TERECOP project. In *EuroLogo* 40, 19-24.
- Atmatzidou, S., & Demetriadis, S. (2014). How to Support Students' Computational Thinking Skills in Educational Robotics Activities. Paper presented at the Proceedings of 4th International Workshop Teaching Robotics, Teaching with Robotics & 5th International Conference Robotics in Education, Padova, Italy.
- Atmatzidou, S., & Demetriadis, S. (2016). Advancing students' computational thinking skills through educational robotics: A study on age and gender relevant differences. *Robotics and Autonomous Systems*, 75, 661-670.

- Bers, M. U., Flannery, L., Kazakoff, E. R., & Sullivan, A. (2014). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Computers & Education*, 72, 145-157.
- Bocconi, S., Chiocciariello, A., Dettori, G., Ferrari, A., Engelhardt, K., Kampylis, P., & Punie, Y. (2016). Developing computational thinking in compulsory education. *European Commission, JRC Science for Policy Report*.
- Brennan, K., & Resnick, M. (2012, April). New frameworks for studying and assessing the development of computational thinking. In *Proceedings of the 2012 annual meeting of the American Educational Research Association, Vancouver, Canada*, 1-25.
- Catlin, D., & Woollard, J. (2014, July). Educational robots and computational thinking. In *Proceedings of 4th International Workshop Teaching Robotics, Teaching with Robotics & 5th International Conference Robotics in Education*, 144-151.
- Cresswell, J. W. (2014). Penelitian kualitatif & desain riset. *Yogyakarta: Pustaka Pelajar*.
- Eguchi, A. (2014, July). Robotics as a learning tool for educational transformation. In *Proceeding of 4th International Workshop Teaching Robotics, Teaching with Robotics & 5th International Conference Robotics in Education Padova (Italy)*.
- Kamal, F., Budiyanto, C. W., & Efendi, A. (2018, November). Understanding students behavior during the adoption of modular robotics in learning. In *IOP Conference Series: Materials Science and Engineering*, 434(1), p. 012263. *IOP Publishing*.
- Karim, M. E., Lemaignan, S., & Mondada, F. (2015). A review: Can robots reshape K-12 STEM education?. In *Advanced Robotics and its Social Impacts (ARSO), 2015 IEEE International Workshop on*, 1-8. *IEEE*.
- Kazimoglu, C., Kiernan, M., Bacon, L., & Mackinnon, L. (2012). A serious game for developing computational thinking and learning introductory computer programming. *Procedia-Social and Behavioural Sciences*, 47, 1991-1999.
- Miglino, O., Lund, H. H., & Cardaci, M. (1999). Robotics as an educational tool. *Journal of Interactive Learning Research*, 10(1), 25.
- Miles, M. B., Huberman, A. M., & Saldana, J. (1984). *Qualitative Data Analysis: A Methods Sourcebook*. *Sage Publications Ltd (CA)*.
- Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York: Basic Books, Inc.
- Weese, J. L., & Feldhausen, R. (2017). STEM Outreach: Assessing Computational Thinking and Problem Solving. Paper presented at the 2017 ASEE Annual Conference & Exposition.
- Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33-35.
- Wing, J. M. (2008). Computational thinking and thinking about computing. *Philosophical Transactions of the royal society of London A: mathematical, physical and engineering sciences*, 366(1881), 3717-3725.

Identifying Students' Misconceptions of Acid-Base Concepts Using a Three-Tier Diagnostic Test: A Case of Indonesia and Thailand

Febriati Dian MUBAROKAH¹ , Sri MULYANI¹, Nurma Yunita INDRIYANTI¹

¹ Department of Chemistry Education, Universitas Sebelas Maret, Indonesia

Received: 20.06.2018

Revised: 20.09.18

Accepted: 15.12.2018

The original language of article is English (v.15, n. Special Issue, December 2018, pp. 51-58, doi: 10.12973/tused.10256a)

ABSTRACT

Through a descriptive exploratory research design, the current study purposed to diagnose students' misconceptions of acid-base concepts. A Three-Tier Diagnostic Test (TTDT) with 20 items was administered to 72 Thai and 64 Indonesian grade 12 students in the science program. The semi-structured interview was used to probe their responses to the interview questions. Then, their misconceptions were classified under four categories. The result indicated that the Thai and Indonesian students' misconceptions were similar to each other. Most of the students had misconceptions of such concepts as acid-base theories, the strength of acids and bases, pH concept in electrolyte and non-electrolyte characteristics of acids and bases. The results shed more light on students' conceptual understanding. Students should be encouraged to overcome their misconceptions and change them scientific conceptions.

Keywords: acids and bases, chemistry education, misconceptions, three-tier diagnostic test

INTRODUCTION

National educational researches recommend to establish new insights for further learning. Variation in the variables will be more various in the multiple countries. Involving a cross-cultural research within two countries appears some biases, i.e, a researcher's educational background [1]. In addition, understanding another country's science education improves researchers' insights into their national science education [2].

Some researchers have compared their countries' science education programmes with one another and improved their own ones. For example; a study investigated how to teach mole concept at sub-microscopic level in Indonesia and German [3]. This study indicated both countries had different understanding level in the mole concept. Then, a research found the similarities and differences of the English and Turkish students' understanding of genetics concepts [4]. Students' insights from various educational contexts in both countries can be beneficial and significant to identify their pitfalls and learning qualities [5].



Several of the ASEAN countries have a 12-year formal education, i.e., Indonesia and Thailand. Indonesian government started this rule in 1970 to promote an educational equity, while Thailand begun it in 1940. The 12-year formal education is divided into primary, lower secondary and upper secondary levels. The secondary school subjects (i.e., science) in these countries are rather similar [6]. Trend in International Mathematics and Science Study (TIMSS) in 2011 showed that Indonesia's and Thailand's science scores ranked the 40th and 27th out of 45 countries respectively. Examining these countries' achievement levels will be interesting to know more about the Thai and Indonesian students' understanding of some science concepts.

Students sometimes bring their pre-existing knowledge to the class. These pre-conceptions are not consistent with scientific ones. After studying in the class, such factors as inappropriate teaching methods and materials may cause misconceptions, called school-made misconceptions [7]. After investigating the Thai and Indonesian students' misconceptions, the current study will highlight the students' school-made misconceptions.

Students' incomplete knowledge explicitly occur misconceptions [13], which have become a central issue in science education since the past three decades [7–12]. Students' misconceptions of acids and bases are very well documented in such countries as Queensland [14], Turkey [15–18], Malaysia [19], New York [20], Thailand [21] and Indonesia [22–24]. This study will focus on the Thai and Indonesian students' misconceptions of acid-base concepts.

All researchers have used different assessment types to identify students' misconceptions of acids and bases. In this study, the authors used a Three-Tier Diagnostic Test (TTDT of Acids and Bases) consisting of multiple-choice questions. The first tier is a usual multiple-choice test, while the second tier asks for its reason. The third tier inquiries their confidence levels for their answers in the first and second tiers [12].

Because students' misconceptions are often similar to each other despite of different culture, religion, and language [25]. Hence, the present study is unique to focus on two different countries (e.g., Indonesia and Thailand) with different cultures, religions, and languages. Hence, the objective of this study was to diagnose the Thai and Indonesian grade 12 students' misconceptions of acids and bases by using the TTDT of Acids and Bases and to clarify their reasons through a semi-structured interview protocol.

METHODOLOGY

Through a descriptive exploratory research design, the sample of the current study comprised of 136 grade 12 students purposefully selected from two schools in Indonesia and Thailand. The researchers used the TTDT of Acids and Bases to identify their misconceptions. This instrument was developed from previous studies by Amry, Sri, and Yahmin [26], Bayrak [18] and Cetin-Dindar and Geban [17]. To check its content validity, two chemistry lecturers, three chemistry teachers (two from Thailand and one from Indonesia) went over the instrument. Its revised version of the TTDT of Acids and Bases (with 20 items) was administered to 136 grade 12 students (72 Thai students and 64 Indonesian students). They responded the TTDT of Acids and Bases within 45 minutes. The TTDT of Acids and Bases contained 4 fundamental concepts, i.e., acid-base theories, the strength of acids and bases, pH concept in electrolyte and non-electrolyte characteristics of acids and bases. To triangulate the results from the TTDT of Acids and Bases, semi-structured interview protocols were conducted to clarify their responses and reasons students' misconceptions of the acid-base concepts.

a) Data Collection

The participants were informed one week before the test. In Thailand, the researchers employed a Thai version of the TTDT of Acids and Bases validated by two Thai chemistry teachers and one Thai chemistry lecturer. Later, its Indonesian version of the TTDT of Acids and Bases was used. All students responded it about 45 minutes. Then, their responses to the TTDT of Acids and Bases were analyzed. Afterwards, their misconceptions and percentages were identified and calculated. In addition, nine Thai students and three Indonesian students were interviewed to clarify their responses and to investigate their reasons of Acid-Base misconceptions. Interviewees were selected based on their responses to the TTDT. Each interview session took about 5-10 minutes. All interviews were tape recorded and transcribed for analysis.

b) Data Analysis

Each item was analyzed via four categories provided by Kaltakci and Didi: scientific knowledge, lack of knowledge, error and misconception [27]. The criteria were figured out at Table 1.

Table 1. Categories in the TTDT of Acids and Bases adapted from Kaltakci et al. (2007)

Categories	Response Types	Code
Scientific Knowledge	correct response + scientific explanation + sure	SK
Lack of Knowledge	correct response + scientific explanation + not sure incorrect response + scientific explanation + not sure correct response + unscientific explanation + not sure incorrect response + unscientific explanation + not sure	LoK
Error	incorrect response + scientific explanation + sure	E
Misconception	correct response + unscientific explanation + sure incorrect response + unscientific explanation + sure	M

RESULTS AND DISCUSSION

Data were tabulated and grouped for each tier. As seen in Figure 1, the percentages of the students, who answered correctly to the TTDT of Acids and Bases from all items, they performed better in their first tiers. In the second and third tiers, the percentages of the correct answers decreased. The same pattern appeared for the Indonesian and Thai students.

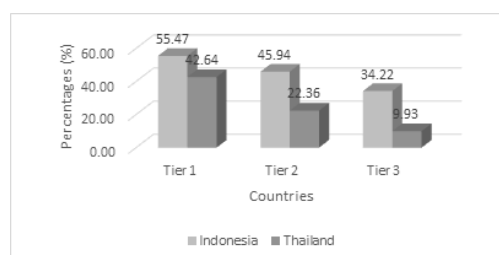


Figure 1. Percentages of the students

These results are consistent with earlier researches using two-tier diagnostic instruments [30]. Almost all of the students had better results in the first tier than other tiers. It also means that a three tier diagnostic test is the most effective assessment to diagnose students' misconception of acids and bases as compared with conventional multiple choice and two tier diagnostic tests. The three tier diagnostic test accurately detected the students' misconceptions with a lack of knowledge or confidence level [12].

As observed in Table 2, the percentages of the Indonesia and Thailand students' misconceptions were similar to one another. These misconceptions may stem from the students' different cultures, religions, and languages [25].

Table 2. Percentages of the Indonesia and Thai Students' Misconceptions of the TTDT of Acids and Bases

Item Number	Concepts	Items	Percentages (%)	
			Misconceptions (M)	
			Thai	Indonesian
1	Acid-Base Theories	1	31.94	37.50
		2	34.72	15.63
		3	29.17	31.25
		4	19.44	10.94
		5	18.06	23.44
	Mean		26.67	23.75
2	The Strength of Acids and Bases	6	15.28	26.56
		7	44.44	60.94
		8	37.50	57.81
		9	26.39	56.25
		10	23.61	57.81
		11	20.83	17.19
		12	37.50	25.00
		13	43.06	25.00
	Mean		30.25	42.53
3	pH Concept in the Environment	15	31.94	10.94
		16	18.06	15.63
		17	9.72	15.63
	Mean		19.91	14.06
4	Electrolyte and Non-electrolyte Characteristics of Acids and Bases	18	41.67	43.75
		19	26.39	40.63
		20	23.61	43.75
	Mean		30.56	42.71
	Overall mean value		26.84	30.76

As seen in Table 2, the Thai and Indonesian students possessed some similar misconceptions. For example; both of them understood the concepts regardless of the contextual factors. But, conceptualizations took place as an influence of different educational contexts [4].

Given the four concepts in this diagnostic test, the highest percentage was belonging to 'Electrolyte and Non-electrolyte Characteristics of Acids and Bases Concept'. Almost all of the students viewed KOH as the only solution that can conduct electricity, since only strong base with a stronger covalent bond can conduct an electric current. A quotation is presented as follows (R: Researcher and S: Student):

R: How about number 18, do you know the answer?

S: That's absolutely A.

R: You're really sure with your answer, why do you choose it?

S: because KOH is the strongest one, so it will conduct the electric current.

As can be clearly seen from the dialogue, the students thought that electricity conductivity was dependent on the strength of the acid-base solution(s). This means that they did take the dissociation value of the solution into account.

Scientifically, the dissociation of a solution determines its electrolyte or non-electrolyte type. Since the solution dissociate in aqueous, it produces ions too. These ions are free to move in solution, therefore the solution conducts electricity. Whatever acids and bases are strong or weak, they have ions that are free to move in an electrolyte solution. The only difference between them is the strength of the electricity produced by the solution.

The percentages of the Thai and Indonesian students' misconceptions of the strength of acids and bases concept were 30.25 and 42.53 respectively. They considered that knowing pH of the solution was enough to identify a strong or weak acid because an increase in pH value decreases its acid strength. An excerpt is in the following:

S: Hm, really? When I read this answer, I just see the pH that will determine the characteristic of the solution, so I absolutely chose it.

R: So, when you read this question, you thought that pH value was the only one determining acidity or basicity of the solution?

S: Yeah, I think so.

As seen from the excerpt, the teacher's explanation of this concept affected their understanding. Most of them saw pH value as the only one to determine the characteristic of the solution. Scientifically, the dissociation of the solution determines a strong or weak acidity of a solution. If the acids are strong, the number of the dissociation is higher than that of the weak one. Even, strong acids or bases completely dissociate in aqueous solution to produce ions. This result is in a parallel with the study by Artdej et al [21] in Thailand. So it proves that misconceptions are resistant to change, persistent, and difficult to relieve in the usual class [31].

The percentages of the Thai and Indonesian students' misconceptions of the acid-base theory were 26.67 and 23.75 respectively. These students chose CH_3COOH as a base solution because it contains OH^- ion. This means that some students had some misconceptions of the concept of acid and base. In view of Demircioglu [15], students consider that the compound with H is an acidic solution while the compound with OH is alkaline. This is in line with the case in Item 2. A sample excerpt is as follows:

S: ... This compound contains OH, so I choose it as a base

R: Hm, do you still remember about acid-base theory that explain about this?

S: Brownsted-Lowry, Arrhenius and lewis?

R: Yes that's right, could you connect it to this question?

S: Sorry, but I am still confused how to differentiate the theory in the question

R: I see.....

As can be seen from that dialogue, grade 12th students were confused with the acid-bases theory that would affect their understanding. Scientifically, CH_3COOH is a vinegar solution that we often meet in our daily life. That appears why students should understand the characteristic(s) of the vinegar. However, many students still had misconception about it. Therefore, context-based learning should be used to enhance their understanding levels. Hence, they may have an opportunity to make abstract concepts more understandable.

The lowest percentages of the Thai and Indonesian students' misconceptions was pertaining to the pH concept in the environment. Their answers were equally distributed. They answered correctly to the first tier, but wrong for the reason tier. The fact that all reason options were equally chosen by the students may result from inability to relate the pH change of a solution with the relevant factors.

Some findings of the current study were practically similar to some previous studies in varied countries, e.g., Turkey [17]. The results emphasized that the TTDT of acids and bases was an effective way to diagnose their misconceptions by differentiating their understanding levels from each other. Students sometimes know the answers but they cannot give their reasons to the answers. By using the TTDT of acids and bases teacher will get insight into their understanding and make some plans to solve any difficulty. Even though students have different languages, cultures, and religions, misconceptions are frequently similar for students at different countries. For example, the results of the present study is similar to such different countries as Queensland [14], Turkey [16], Malaysia [19], and New York [20]. They found similar misconceptions despite of the use of different assessment tools. The TTDT of acids and bases can help teachers effectively elicit their understanding levels because it is time-efficient, easily applicable and effective for accessing many students.

CONCLUSION and IMPLICATION

The Thai and Indonesian students, who had different cultures, religions, and even languages, possessed the same problems in studying the chemistry concepts, especially acid-base concepts. Some misconceptions are in the following:

- 30.56 % of the Thai students and 42.71 % of the Indonesian students thought that only strong acid or base solutions could conduct electricity,
- 30.25 % of the Thai students and 42.53 % of the Indonesian students considered that pH value was the only one to determine the characteristic(s) of the solution,
- 26.67 % of the Thai students and 23.75 % of the Indonesian students viewed CH_3COOH as a base solution because it contains OH^- ion,
- Most of the students was confused with differentiating the acid-base theory from each other,
- 19.91 % of the Thai students and 14.06 % of the Indonesian students were unable to relate the pH change of a solution with the relevant factors.

Therefore, teachers should pay more attention to this problem. The TTDT of Acids and Bases can be used to investigate students' misconceptions. Afterwards, teacher will decide what students need to know the concept(s) scientifically. Hence, they may encourage students to confront their misconceptions and to change their understanding towards a scientific concept.

The results of this study can be a reference for teachers to deliver the subject so that students eliminate their misconceptions and understand the concept(s) correctly. Thus, teachers may know and synchronize students' pre-conceptions before teaching a new concept. Then, teachers are able to prepare appropriate method(s) to instruct acid-base concepts by refraining from new misconception(s).

ACKNOWLEDGMENT

The research was supported by the SEA-Teacher Program and the Faculty of Teacher Training and Education, Universitas Sebelas Maret in 2017.

REFERENCES

- Amry, U.W., Sri, R. & Yahmin,. (2016). Pengembangan Instrumen Tes Diagnostik Two-Tier pada Materi Asam Basa. *Pros. Semnas Pend. IOA Pascasarjana UM*, 1, 715–722.
- Artdej, R., Ratanaroutai, T., Coll, R. K., & Thongpanchang, T. (2010). Thai Grade 11 students' alternative conceptions for acid–base chemistry. *Research in Science & Technological Education*, 28(2), 167-183.
- Barke, H.D., Hazari, A., & Yitbarek, S. (2009). Acid – Base Reactions, *Misconceptions in Chemistry*, 173–206.
- Cetin-Dindar, A., & Geban, O. (2011). Development of a three-tier test to assess high school students' understanding of acids and bases. *Procedia-Social and Behavioral Sciences*, 15, 600-604,
- Damanhuri, M. I. M., Treagust, D. F., Won, M., & Chandrasegaran, A. L. (2016). High School Students' Understanding of Acid-Base Concepts: An Ongoing Challenge for Teachers. *International Journal of Environmental and Science Education*, 11(1), 9-27.
- Demircioglu, G., Ayas, A., & Demircioglu, H. (2005). Conceptual change achieved through a new teaching program on acids and bases. *Chemistry Education Research and Practice*, 6(1), 36-51.
- Fraser, B. J., Aldridge, J. M., & Adolphe, F. G. (2010). A cross-national study of secondary science classroom environments in Australia and Indonesia. *Research in Science Education*, 40(4), 551-571.
- Gurel, D. K., Eryılmaz, A., & McDermott, L. C. (2015). A Review and Comparison of Diagnostic Instruments to Identify Students' Misconceptions in Science. *Eurasia Journal of Mathematics, Science & Technology Education*, 11(5).
- Hand, B. M., & Treagust, D. F. (1988). Application of a conceptual conflict teaching strategy to enhance student learning of acids and bases. *Research in science education*, 18(1), 53-63.
- Haslam, F., & Treagust, D. F. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple choice instrument. *Journal of biological education*, 21(3), 203-211.
- Indriyanti, N. Y., & Barke, H. D. (2017, August). Teaching the mole concept with sub-micro level: Do the students perform better?. In *AIP Conference Proceedings* (Vol. 1868, No. 1, p. 030002). AIP Publishing.
- Kaltakçı, D., & Didiş, N. (2007, April). Identification of Pre-Service Physics Teachers' Misconceptions on Gravity Concept: A Study with a 3-Tier Misconception Test. In *AIP Conference Proceedings*, 899(1), 499-500, AIP.
- Kılıç, D., Taber, K. S., & Winterbottom, M. (2016). A Cross-National Study of Students' Understanding of Genetics Concepts: Implications from Similarities and Differences in England and Turkey. *Education Research International*, 2016.
- Lemmer, M., Kriek, J., & Erasmus, B. (2018). Analysis of students' conceptions of basic magnetism from a complex systems perspective. *Research in Science Education*, 1-18.
- Muchtar, Z. (2012). Analyzing of students' misconceptions on acid-base chemistry at senior high schools in Medan. *Journal of Education and Practice*, 3(15), 65-74.
- Mulford, D. R., & Robinson, W. R. (2002). An inventory for alternate conceptions among

- first-semester general chemistry students. *Journal of chemical education*, 79(6), 739.
- OECD (2009). PISA 2006 Programme for International Student Assessment.
- Othman, J., Treagust, D. F., & Chandrasegaran, A. L. (2008). An investigation into the relationship between students' conceptions of the particulate nature of matter and their understanding of chemical bonding. *International Journal of Science Education*, 30(11), 1531-1550.
- Peterson, R. F., & Treagust, D. F. (1989). Grade-12 students' misconceptions of covalent bonding and structure. *Journal of chemical education*, 66(6), 459.
- Peterson, R., Treagust, D., & Garnett, P. (1986). Identification of secondary students' misconceptions of covalent bonding and structure concepts using a diagnostic instrument. *Research in Science Education*, 16(1), 40-48.
- Pinarbasi, T. (2007). Turkish undergraduate students' misconceptions on acids and bases. *Journal of Baltic Science Education*, 6(1), 23-24.
- Ross, P. (1994). The relevance of the term 'misconception'. *Research in Science Education*, 24(1), 376-377.
- Sadhu, S., Tima, M. T., Cahyani, V. P., Laka, A. F., Annisa, D., & Fahriyah, A. R. (2017, August). Analysis of acid-base misconceptions using modified certainty of response index (CRI) and diagnostic interview for different student levels cognitive. In *International Journal of Science and Applied Science: Conference Series*, 1(2), 91-100).
- Sheppard, K. (2006). High school students' understanding of titrations and related acid-base phenomena. *Chemistry Education Research and Practice*, 7(1), 32-45.
- Taber, K. (2002). *Chemical misconceptions: prevention, diagnosis and cure* (Vol. 1). Royal Society of Chemistry.
- Taber, K. S. (2012). Vive la différence? Comparing "like with like" in studies of learners' ideas in diverse educational contexts. *Education Research International*, 2012.
- Treagust, D. (1986). Evaluating students' misconceptions by means of diagnostic multiple choice items. *Research in Science education*, 16(1), 199-207.
- Turgut, Ü., Gürbüz, F., & Turgut, G. (2011). An investigation 10th grade students' misconceptions about electric current. *Procedia-Social and Behavioral Sciences*, 15, 1965-1971.
- UNESCO, Education Systems in ASEAN + 6 Countries : A Comparative Analysis Selected Educational Issues. 2014.
- Widarti, H. R., Permanasari, A., & Mulyani, S. (2017). Undergraduate students' misconception on acid-base and argentometric titrations: a challenge to implement multiple representation learning model with cognitive dissonance strategy. *International Journal of Education*, 9(2), 105-112.

Activity and Progress of Learning with Two Stay Two Stray (TS-TS) Cooperative Model on Harmonic Vibration

MUJASAM¹ , S G M RENITA¹, and A Y T ALLO¹

¹Jurusan Pendidikan Fisika Universitas Papua Jl. Gunung Salju Amban Manokwari Papua Barat, Indonesia

Received: 20.06.2018

Revised: 20.09.18

Accepted: 15.01.2019

The original language of article is English (v.12, n.3, September 2015, pp.3-20, doi: 10.12973/tused.10143a)

ABSTRACT

Two stay two stray cooperative model (TS-TS) has been applied to know the activity and progress of student learning outcomes in Yapis Manokwari Senior High School. The type of research used is quantitative with quasi-experimental method. Time series design research was used, in this case, the group used for research cannot be selected at random. The sampling technique used is purposive sampling. This technique selects samples with certain criteria which in this research is class X IPA as many as 12 students. The data collected were pre-test, post-test and learning activity for three lessons with harmonic vibration material. The results of pre-test and post-test data collection has tested the hypothesis using Paired Sample T-Test with , obtained $t = 5.920 > t_{table} = 1.796$, then rejected . This shows that after applied TS-TS learning model there is a significant difference in student learning outcomes before asked the model and afterwards. The N-Gain test also shows an increase of the post-test average of each learning. Students' activity on each learning has increased by 40.7%, 48.8% and 63.2%, respectively. Physics learning using TS-TS learning model can help learners to understand the physical meanings of physics and solve/analyze the problems given by the teacher and can increase learners' learning activities during the learning process.

Keywords: activity, cooperative model, learning of progres, two stay two stray (TS-TS)

INTRODUCTION

The emphasis on the process of analyzing the problems in physics requires a deeper learning of physics, therefore to learn more than the students must understand the concepts of the previous material. This fact should be followed by appropriate and adequate physics learning (Gunta, 2015). It is not unknown that the subject of physics in Indonesia is a lesson that is considered difficult, heavy and unpopular so that in the end can reduce the interest of learners to learn it (Wulandari, 2016). One of the efforts that can be done for that purpose is to use the right learning model. The basic activities that learners use for learning are speaking, listening, writing, reading, doing experiments, and observing. It is expected that the desire of learners in the class will be maximized to make learners as the center of learning. The teacher's job is to motivate students so that they will carry out a series of learning activities. High

motivation of the students is expected to drive the students' interest in learning so that student learning outcomes can be improved (Palupi, 2014).

Cooperative learning will encourage learners to solve a given problem and be able to discuss such issues with their peers. In other words, teachers can engage high-ability learners to help their peers with low-ability. The cooperative learning can increase activity and learning outcomes (Celikten, 2012). Learners in completing the task group, each member cooperate and help to understand a learning material.

Teaching and learning process is one of the things that are needed and influential in the achievement of learning objectives. Learning activities of learners as a requirement in the learning process is necessary because learning may not take place properly without the activity of learning process. This indicates that an effective learning process is going to have an effective impact on the results of the learning process. In the learning process, learning activities should involve all aspects of students, both in physical and mental. So, changes in behavior can change quickly, precisely, easily and correctly related cognitive, affective and psychomotor aspects (Hanafiah, 2010). In this learning activity, learners must be active in the following the learning processes to develop the potential that exists in them.

Learning activities of learners (Supinah, 2013) can be described as follows:

- Complex thinking: Students use of various complex thinking strategies effectively and translate a task into a working step with clear objectives.
- Processing information: Students use different information-gathering techniques and information resources effectively and interpret and synthesize information.
- Communicate effectively: Students express/convey ideas clearly and effectively communicate ideas with other people/students.
- Working together or collaborating: Students are trying to achieve group goals by using interpersonal skills effectively, strive to maintain group cohesiveness, and demonstrate the ability to play roles in various roles effectively.
- Effective reasoning: Students understand their own paradigms, make effective plans, seek, create and use the required resources, and be very sensitive to feedback.

Yapis Manokwari Senior High School is one of the schools that have been using the Curriculum 2013. Teachers should be experienced by learners to able to know the conditions and situations for the implementation of learning. If the knowledge of these conditions is fulfilled the learning process can run smoothly and optimally. Initial conditions found in Yapis Manokwari Senior High School. Teachers tend to still be the center of learning (teacher center). This kind of learning does not provide an opportunity for learners to express their opinions and ideas which leads learners to be less active in the learning process. The teacher who in this case is a physics teacher should be able to provide a physics learning atmosphere that is fun and not stressful for learners. One way that can be done is to choose the appropriate learning model. Also, the learning model should be able to make learners active in the learning process. The activity of learners is going to affect the learning outcomes of the learners (Tsay, 2006).

The cooperative learning model is a learning model that requires learners to work together in small groups and help each other in learning to achieve learning objectives (Huda, 2011). One of the used cooperative learning models is Two Stay Two Stray (TS-TS) type. The TS-TS type cooperative learning model developed by Spencer Kagan is a learning model that provides an opportunity for group members to share results and information with other group members by visiting each other or visiting groups (Nardi, 2014). The reason to choose this learning model is enabling learners to interact with each other and share their knowledge with other friends. In this type, there is a given role as host and guest. This role is used during group discussions. The existence of the given role to the learners will motivate the learner to understand the material which will be delivered during the inter-group discussion. In the way, learners are required to

be able to understand the material. The expected learning is learning that focuses on the activities of learners which enable learners to be directly involved in learning. Appropriate learning model can motivate learners to increase physics learning activities and results (Dewi, 2016). The TS-TS type cooperative model is more effectively used to improve learning outcomes compared to other models (Wahyuni, 2014; Gumay, 2014; Nurjanah, 2017).

The TS-TS type of cooperative learning model has a founder in the implementation which relate in activities undertaken by learners during the learning process. Each group consists of two people who serve as guests and two people who play the role of the host. The two people in each group are going to visit the other group, ask the material and the host of the other group members to explain the material to the visiting group members (Suprijono, 2009). This model provides an opportunity for learners to discuss each other's problems with peers and share information gained in the group to other groups. The use of TS-TS type cooperative learning model provides a funny learning experience for students because learners can solve problems with friends and convey/communicate the solution with other groups in the role of guest and host (Harahap, 2017).

METHODOLOGY

The research method used in this research is quasi-experimental design as one of the quantitative methods. The quasi-experiments are defined as an experiment that has the treatment and measurement of the effect of the treatment (Riduwan, 2011). In this method, the researcher has a role as a controller in order to completely control the characteristics of the sample to be studied, the characteristics of the sample to be studied and using a design that allows to be used as a controller of the situation.

The quasi-experiments have two forms of design as time series design and nonequivalent control group design (Sugiyono, 2016). The time series design used in this study. In this design, the used groups cannot be randomly selected for the study. Before the treatment, the group was pretested up to three times, to know the stability and clarity of the group's condition before being treated. If the score in each group has the same value at the pretest and then the value is much increased after being given posttests, it will be more reliable if the treatment causes improvement to be done more than one pretest and posttest given (Fraenkel, 2009).

Sampling technique used in this research was purposive sampling. The purposive sampling is a technique of selecting samples with condition sampling. Some of the considered criteria are the number of learners in a class, the inactivity of learners in the classroom and the cognitive learning outcomes of learners on the low level of physics. The sample used in this research is X class IPA Yapis Manokwari Senior High School. This is done because researchers do not use a comparison class. In class X IPA, the number of students was 12. This criterion has been adapted from the TS-TS type cooperative learning model because the learners will be divided into the groups consisting of 4 students.

Data collection techniques consist of observation, documentation, and tests. Learning progress data obtained from learners' learning outcomes during the process of teaching and learning activity that is at the value of pretest and posttest. Data obtained from the observation sheet of learner activity.

Procedures of activities undertaken in analyzing the data activities of learners are as follows:

1. Provide an assessment with a range of 1-5 for each aspect assessed by providing a check mark on the assessment sheet.
2. The assessment sheet using Likert scale with 5 criteria is very good, good, good enough, less, and very less. These criteria have information about the number of

learners who made the statement on the observation sheet. After the observer fills in the observation sheet, then adds a lot of checks to each column on the observation sheet.

The pretest and posttest data tested the normal and homogeneous model classes as the basis for determining hypothesis testing, then using N-gain to calculate the improvement that occurred before the learning and after model learning.

RESULT and DISCUSSION

a) Activity of Learning

Student learning activity in table 1, when applied cooperative learning model type TS-TS, learning activities get increasing percentage. Student learning activities are observed in two categories as class and group. The assessment of one class category, the percentage of activity in the first learning was 40.7%. This value was included in the medium criterion. In the second study rose to 48.8%. This value included in the criterion of medium. At the last learning was 63.2% of this value included in high criteria. In group appraisal, the percentage of activities found that during the first and second period of the study included moderate criteria, in which only a few students provided feedback on the teacher's lessons. However, the three activities of learners are at a high criterion in learning where learners almost do whole learning activities well. In the third lesson, learners participated fully in the discussion activities, and conveyed the results of group discussion to other groups. The Finding are in line with the study (Simone, 2016) which says that learners participate fully in discussion activities, giving roles and responsibilities convey the results of group discussion to other groups.

Table 1. Percentage of learning activities in class and group categories

		Unit	%		
			Class		
Class activity	1.	Harmonic Vibration Characteristics	40,7		
	2.	Period, Frequency, and Vibration Energy	48,8		
	3.	Harmonic Vibration Energy	63,2		
			Group		
Group Activity	1.	Harmonic Vibration Characteristics	46,7	46,7	39,0
	2.	Period, Frequency, and Vibration Energy	59,0	50,4	53,1
	3.	Harmonic Vibration Energy	75,2	77,1	74,2

Based on Figure 1.a, percentage of learning activities of students in the classroom increased from learning 1, 2, and 3. The result of this percentage was obtained from the observation on the activity sheet. Based on the percentage criteria of learners' learning activities, the percentage goes into medium to high criteria. Based on Figure 1b, the results of the activity assessment of learners in terms of groups indicating that each learning has increased significantly, and this is in the middle to high level, the average of each learning is 44.1%, 54.0% and 78.8%. The percentage increase for group 1 in learning 1 to 2 was 12.3%, in the 2nd to 3rd learning was 16.2%. Group 2 in learning 1 to 2 amounted to 3.7%, in learning 2 to 3 of 26.7%. Group 3 in learning 1 to 2 was 14.1%, in learning 2 to 3 of 21.1%.

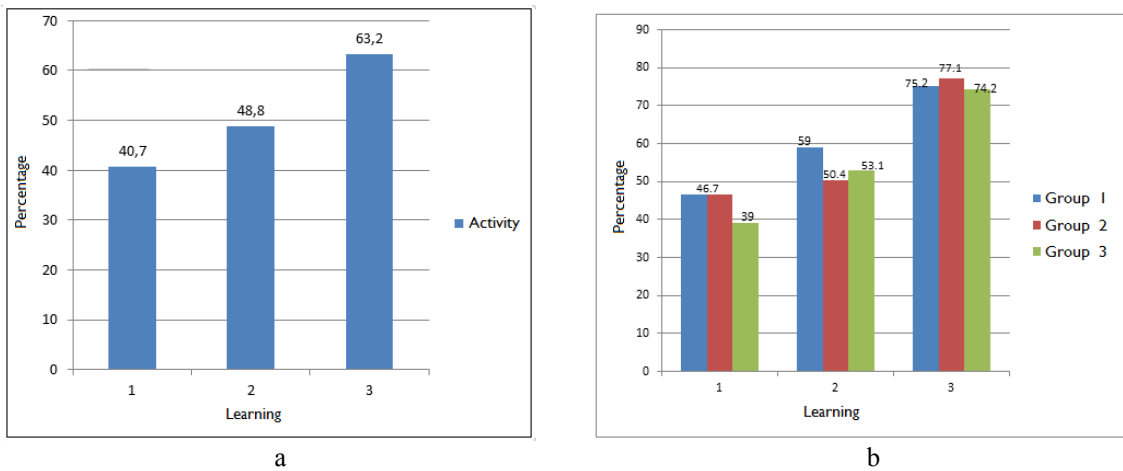


Figure 1. Graph of percentage of assessment, a) Class activity, and b) Group activity

b) Progress of TS-TS Cooperative Learning Model

Improved learning outcomes can be seen from the behavior in addition to the mastery of knowledge, thinking skills and motor skills. Results of learning or student achievement can be seen from the mastery of material that has been studied. Tools for measuring results/learning achievements prepared by the teacher named achievement test.

Table 2. Significance of normality and homogeneity test data, a) kolmogorov-smirnov, b) Levene statistic

Method	Normality Test (Kolmogorov-Smirnov)			Homogeneity Test (Levene Statistic)			
	Statistic	df	Sig	Statistic	Df1	Df2	Sig
Pre-test	0,213	12	0,140	0,033	1	22	0,858
Pos-test	0,193	12	0,200				

Table 2 (a) shows that the value of pre-test significance is 0.140 and post-test 0.200, with then significance > 0,05. These results indicate that the data is normally distributed. Table 2 (b) shows that the significance value of the data on the homogeneity test is 0.858, with the value then the significance > 0,05. This means that the data is homogeneous. After it is confirmed to be normally distributed and homogeneous, the data analysis is continued by hypothesis/inference test using Paired Sample t-test.

Table 3. Cognitive diagnostic tests on the mean pretest and posttest values

	Paired Samples Test						
	Paired Differences						
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df
	Lower	Upper					
Pair 1 posttest - pretest	22.048	12.901	3.724	13.851	30.246	5.920	11

Table 3 is the result of paired Sample t-test performed at pretest and posttest value with significant level obtained = 5,920, while value = 1,796 so > then rejected. This means that there are significant differences in cognitive learning outcomes before and after using TS-TS type cooperative learning model. This significant difference occurs because of differences in pretest and posttest values of learners, the average posttest score is higher than the pretest value of learners. This means that, the application of TS-TS type cooperative learning model give a good enough impact in helping to improve students learning outcomes. In line with the results of the study (Selvianti, 2015) indicating that there are significant differences in physics

learning outcomes of learners who were taught using cooperative learning model type TS-TS and who were taught using conventional learning model.

The N-Gain test is done by calculating the gain formula on N-Gain equation. The result obtained is as follows:

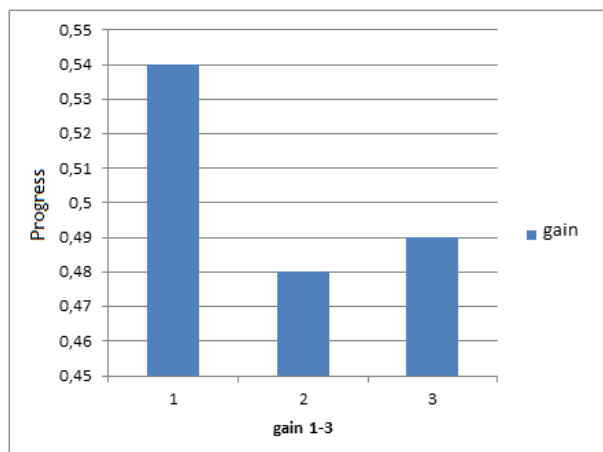


Figure 2. Graph of N-gain test

The N-gain test is performed to see the difference in learners' learning outcomes between before and after learning. Based on Figure 2, the result of g1 is the difference between pretest results 1 and posttest 2, g2 differences in pretest 2 and posttest 2 results, g3 differences in pretest 3 and posttest results 3. The tests show that there is a difference between before and after applying cooperative learning model TS-TS type to outcome learners learn. This is also evidenced by the average posttest score of learners better than the average pretest value of learners. The increase in learning outcomes has previously been proven through research conducted by (Effendi, 2016) showing that TS-TS can improve the results student learning. Along with research results (Lusiana, 2017) that the low motivation and student learning outcomes can be overcome by applying the TS-TS.

CONCLUSION

The use of TS-TS cooperative learning model provides many benefited for students in Yapis Manokwari Senior High School. The result of learning activity is known that students are happier and active in group learning. Student learning activity in one class gives successive percentage of each learning is 40.7%, 48.8%, and 63.2% who experienced an increase in each learning and included in the criteria of medium and high. Student learning activities in the group gave the average percentage of each successive learning was 44.1%, 54.0% and 78.8% in medium and high criteria. Students are free to ask their friends if they feel difficult and they also feel more comfortable. This result is also evidenced by the increase of N-gain in pretest and posttest with moderate criterion that is in the range $0.3 < g < 0.7$, that the posttest average value is better than the average value of pretest learners. It was concluded that learning with TS-TS cooperative model can improve learning activity and learning achievement.

The obstacles faced by most teachers are only about developing the digital teaching materials when the initial planning takes up much of their time. Moreover, most of the teachers are accustomed to use technology for learning, so they have less chance to experience many obstacles. On the other hand, a small number of teachers who are unfamiliar with the technology have more chance to encounter many obstacles in developing it.

REFERENCES

1. Gunta, S. & Ousman, K. (2015). Problems in the Teaching and Learning of Physics at the Preparatory and Preparatory Schools: The case of Wolaita and Dwuro Zones. *Global Journal of Human-Social Science*, **15**(7), 1-5.
2. Wulandari, A. & Sumadi, S. (2016). Hubungan antara Minat, Lingkungan, dan Persepsi Siswa Terhadap Kemampuan Mengajar Guru dengan Prestasi Belajar Fisika. *Jurnal Ilmiah Pendidikan Fisika, COMPTON*, **3**(2), 84-92.
3. Palupi, R., Anitah, S., & Budiyo, B. (2014). Hubungan antara Motivasi Belajar dan Persepsi Siswa terhadap Kinerja Guru dalam Mengelola Kegiatan Belajar dengan Hasil Belajar IPA Siswa Kelas VIII di SMP Negeri 1 Pacitan. *Jurnal Teknologi Pendidikan dan Pembelajaran*, **2**(2), 157-170.
4. Celikten, O., Ipekcioglu, S., Ertepinar, H., & Omer, G. (2012). The Effect of the Conceptual Change Oriented Instruction through Cooperative Learning on 4th Grade Students' Understanding of Earth and Sky Concepts. *Science Education International*, **23**(1), 84-96.
5. Hanafiah, N. & Suhana, C. (2010). *Konsep Strategi Pembelajaran*. Bandung: Refika Aditama.
6. Tsay, M. & Brady, M. (2006). A case study of cooperative learning and communication pedagogy: Does working in teams make a difference? *Journal of the Scholarship of Teaching and Learning*, **10**(2), 78-89.
7. Huda, M. (2011). *Cooperative Learning*. Yogyakarta: Pustaka Pelajar.
8. Nardi, M. (2014). Penerapan Model TSTS dan Carousel Feedback Untuk Meningkatkan Efikasi Diri Dan Prestasi Akademik Siswa. *Jurnal Pendidikan dan Kebudayaan Missio*, **7**(1), 1-19.
9. Dewi, F. D. R., Soetjipto, B. E. & Utaya, S. (2016). The Implementation of TSTS and Round Robin Learning Models to Enhance Communication Skill and Social Studies learning Outcome for the Fourth Grade Students. *Journal of Research & Method in Education (IOSR-JRME)*, **6**(3), 93-100.
10. Wahyuni, I. & Munthe, Y. G. (2014). The Effect of Cooperative Learning Models Type Two Stay Two Stray (TSTS) to Students Result on Dinamic Electricity on Senior High School Students, *Jurnal Pendidikan Fisika*, **3**(1), 1-7.
11. Gumay, O. P. U. (2017). Pengaruh Model Pembelajaran Kooperatif Tipe Two Stay Two Stray Terhadap Hasil Belajar Fisika Siswa Kelas VIII Smp Negeri 3 Lubuklinggau Tahun Pelajaran 2015/2016. *Science and Physics Education Journal (SPEJ)*, **1**(1), 49-58.
12. Nurjannah, N. (2017). The Two Stray Teaching Strategy In Social Education Subject. *Asian Journal of Social Sciences & Humanities*, **6**(4), 44-50.
13. Suprijono, A. (2009). *Cooperative Learning Teori dan Aplikasi Paikem*. Yogyakarta: Pustaka belajar.
14. Harahap, K. A. & Surya, E. (2017). Application of Cooperative Learning Model with Type of Two Stay Two Stray to Improve Result of Mathematics Teaching. *International Journal of Science: Basic and Applied Research (IJSBAR)*, **33**(2), 53-60.
15. Riduwan, R. (2011). *Skala Pengukuran Variabel-Variabel Penelitian*. Bandung: Alfabeta.
16. Sugiyono, P. (2016). *Metode Penelitian Pendidikan (Pendekatan Kuantitatif, Kualitatif dan R&D)*. Bandung: Alfabeta.
17. Fraenkel, J. R. & Wallen, N. E. (2009). *How to Design and Evaluate Research in Education*. McGraw-Hill: New York.
18. Simone, K. & Rietz, C. (2016). Effects of Web-Based Feedback on Students' Learning. *International Journal of Teaching and Learning in Higher Education*, **28**(3), 385-394.

19. Selvianti, S., Ali, M. S. & Helmi, H. (2015). Pengaruh Model Pembelajaran Kooperatif Tipe Two Stay Two Stray Terhadap Aktivitas dan Hasil Belajar Fisika Peserta Didik Kelas XIIA SMAN 1 Lilirilau. *Jurnal Sains Dan Pendidikan Fisika*, **11**(1), 22-33.
20. Effendi, A., Soetjipto, B. E. & Widiati, U. (2016). The Implementation of Cooperative Learning Model TSTS and Carousel Feedback to Enhance Motivation and Learning Outcome for Social Studies. *Journal of Research & Method in Education (IOSR-JRME)*, **6**(3), 131-136.
21. Lusiana, I. A., Setyosari, P. & Soetjipto, B, E. (2017). The Application of Two Stay Two Stray (TSTS) and FanN-Pick Learning Models to Improve Students' Motivation and Learning Outcomes on Social studies Subject (A Study on the Fourth Grade students of SDN Tawun I Ngawi). *International Journal of Academic Research in Progressive Education and Development*, **6**(3), 79-108.

Implementation of E-learning based-STEM on Quantum Physics Subject to Student HOTS Ability

Irfan YUSUF¹ , Sri Wahyu WIDYANINGSIH¹ and Sri Rosepda Br. SEBAYANG¹

¹Jurusan Pendidikan Fisika, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Papua, Indonesia

Received: 20.06.2018

Revised: 20.09.18

Accepted: 15.12.2018

The original language of article is English (v.15.n. Special Issue December 2018, pp. 67-75, doi: 10.12973/tused.10258a)

ABSTRACT

E-learning media is one effective solution as a learning tool that could be implemented anytime and anywhere. Science, Technology, Engineering, and Mathematics (STEM) approach through the use of e-learning is expected to develop students Higher Order Thinking Skills (HOTS). This study aimed to measure students HOTS abilities through the use of e-learning based-STEM media in quantum physics courses. Through purposive sampling technique set sample research that is students who are in the program of quantum physics courses for ten people in the even semester 2017-2018 in Jurusan Pendidikan Fisika Universitas Papua. The instruments used are eight numbers of HOTS questions in the form of essays and questionnaires of student responses given after the lesson. The data analysis technique used was gain test to see if there was the improvement of HOTS student ability and hypothesis test through SPSS to know the difference of HOTS ability before and after learning, while student response questionnaire analysis is done through Rasch modeling using the Winstep program. The results showed that the value of N-gain (0.7) high category and Wilcoxon test significance value (0.004) indicating that learning of quantum physics through e-learning based on the STEM can improve students HOTS capability. Rasch modeling showed that in general the students strongly agree on the learning done. Therefore, the implementation of e-learning based on the STEM in quantum physics course could be used as one of the references to develop students HOTS capability.

Keywords: e-learning, HOTS, response, STEM

INTRODUCTION

The development of science and technology has penetrated in various aspects of life including education. Science and technology today have an essential role in education, in particular, to equip learners with challenges in the future. Science, Technology, Engineering, and Mathematics (STEM) is one alternative that can be applied in science learning to build a generation capable of facing various challenges in the 21st century. Science and technology cannot be separated from the concept of the STEM. Science can be found from the advent of technological products and the opposite, the development of science supports for the

emergence of various cutting-edge technologies. The life skills of learners must meet the needs of today's world that they must be able to work with IT and develop their thinking skills (Wahyuni and Zainnuri, 2017).

The ability to think or known as HOTS is very important to train to learners who are able to develop their abilities in problem solving. The ability HOTS of students is still relatively low in Department of Physics Education, Faculty of Teaching and Education, University of Papua. The low ability of HOTS is affected by lack of student learning motivation (Yusuf and Widyaningsih, 2018). Innovation in learning is essential to be done by educators to improve the motivation to learn that affects the HOTS ability of students. The use of technology can be one of the innovations in learning that can foster the motivation of learners (Suryani, 2017). The use of technology in learning can help learners to understand the material and encourage their perception and motivation to learn (Yusuf and Subaer, 2013; Yusuf, et al., 2015; Iksan and Saufian, 2017).

One of the uses of technology in learning is through the use of e-learning. Learning through e-learning is one of the means of transforming conventional learning into digital form. Utilization of e-learning can eliminate the limits of space and time that happened in education (Gunga and Ricketts, 2007). Learning through the use of e-learning can affect the ability of STEM learners and their interest in science lessons (Proudfoot and Kebritchi, 2017; Popovici and Mironov, 2015). Learning through e-learning can also create learning independence for learners and contribute positively to their learning experiences (Tubaishat and Lansari, 2011).

Therefore, it is necessary to apply e-learning based on the STEM in the quantum physics course to examine HOTS capability of students. The purpose of this study is to measure students HOTS capabilities through the use of e-learning based on STEM-media in quantum physics courses.

METHODOLOGY

This research was quasi-experiment research of one group pretest-posttest design. The purposive sampling technique was used to determine the sample of research which was the student of quantum physic program courses of 10 people in the even semester of 2017-2018 Department of Physics Education, Faculty of Teaching and Education, University of Papua. The instruments used were eight of HOTS questions in essays and questionnaires of student responses given after the lesson. Data analysis technique used was the N-gain test ($\langle g \rangle$) to measure whether there was an improvement of HOTS student ability. The N-gain test equation according to Hake (1998) as in equation (1).

$$\langle g \rangle = \frac{\% \langle S_f \rangle - \% \langle S_i \rangle}{100 - \% \langle S_i \rangle} \quad (1)$$

Where, $\langle g \rangle$ was a normalized gain, $\langle S_i \rangle$ was the average score of the pretest, and $\langle S_f \rangle$ is the posttest average score. N-gain improvement criteria are categorized according to Table 1.

Table 1. Normalized average score criteria

Value $\langle g \rangle$	Criteria
$\langle g \rangle > 0,7$	High
$0,3 < \langle g \rangle \leq 0,7$	Medium
$\langle g \rangle \leq 0,3$	Low

The effectiveness implementation of e-learning based on STEM in the quantum physics course on students HOTS ability could be known based on the effect size value as in equation (2).

$$d = (m_A - m_B) / \left[\left(\frac{sd_A^2 + sd_B^2}{2} \right)^{1/2} \right] \quad (2)$$

Where d was the effect size, m_A was the mean value of posttest, m_B was the average value of pretest, sd_A was the standard deviation of posttest, and sd_B was the standard deviation of pretest (Hake, 2002). The effect size value was categorized based on the criteria as in Table 2 (Cohen, 1992).

Table 2. *Category of effect size*

Effect size	Category
$d < 0,2$	Small
$0,2 < d < 0,8$	Medium
$d > 0,8$	High

Hypothesis testing was done using SPSS program to know the difference between HOTS ability before and after learning. Determination of hypothesis testing technique begins with normality test and homogeneity test of data. If the data was normal and homogeneous distributed then the hypothesis tested through parametric technique. But, if not normal or not homogeneous then the hypothesis tested using non-parametric analysis. Student response questionnaire analysis was done through Rasch modeling using the Winstep program. Winstep provided various features that could help in analyzing respondent ratings. Rasch modeling could proceed more accurate analysis results that had so far been unrivaled by other analytical techniques (Boone, et al., 2014).

RESULT and DISCUSSION

This research begins with giving the pretest to students. Pretest aims to determine the first ability and difficulty faced by students, so hopefully can be done applying the appropriate learning. Preparation of learning begins with the preparation of learning materials into e-learning system includes Semester Learning Plan, material slides, assignments, and evaluation of learning. The material presented on e-learning consists of various reference books and virtual experimental facilities that can be run by students to understand more deeply related to the concept of quantum physics material being studied.

The course of quantum physics consists of abstract concepts and is difficult to describe directly because of its microscopic scope. One solution to explain the abstract material is to include virtual lab media into the e-learning system. The e-learning system can run a variety of media such as video, animation, and virtual experiment simulations that can be run directly by both teachers and learners (Gordillo, et al., 2013). The virtual lab media can be run directly by the learner to understand the experimental principle. Experiments that can be executed virtually by learners include black thing radiation experiments, photoelectric effects, and Compton effects. A virtual experiment can help learners to understand experimental principles like real experiments in a real laboratory. The virtual experiments were conducted with due to consideration to the limitations of laboratory facilities and infrastructure, the dangers posed when the experiments were conducted in a real laboratory, or simulations

performed before the experiments were performed (Azis and Yusuf, 2013). Figure 1 shows the initial appearance of e-learning in Department of Physics Education, Faculty of Teaching and Education, University of Papua and the online classroom display of quantum physics courses.

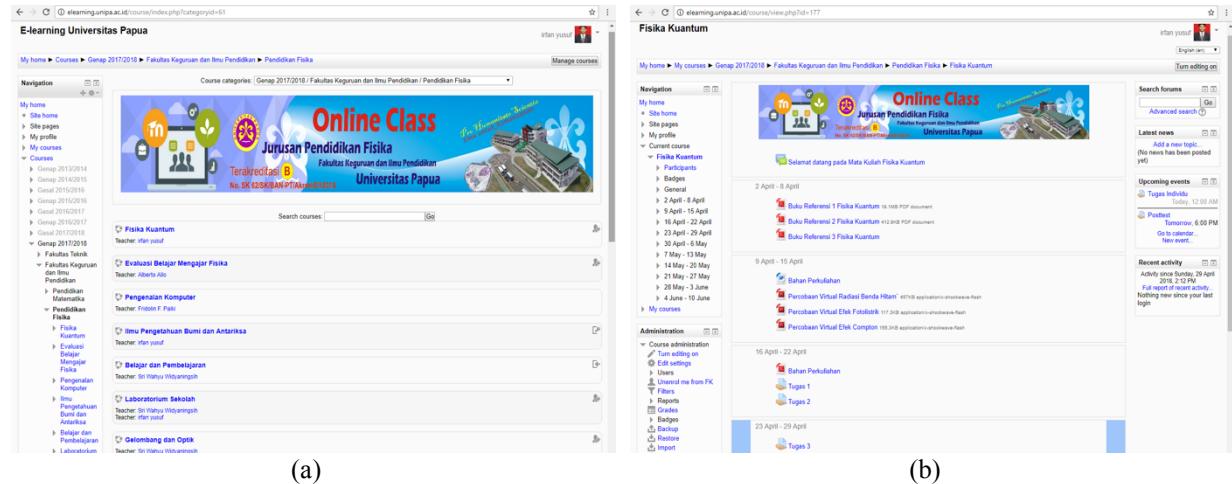


Figure 1. The use of e-learning in learning (a) initial appearance of e-learning in Department of Physics Education, Faculty of Teaching and Education, University of Papua and (b) display of online classes of quantum physics

The study of quantum physics through the utilization of e-learning allows learners to be able to explore and find themselves a concept. A wide variety of reference books and instructional materials are presented directly and accessible whenever and wherever they are both inside and outside the classroom. All students are actively involved in learning. This can be seen from the ongoing online discussions and their enthusiasm in completing the assigned task. Figure 2 shows the active involvement of all students in collecting their assignments online through e-learning.

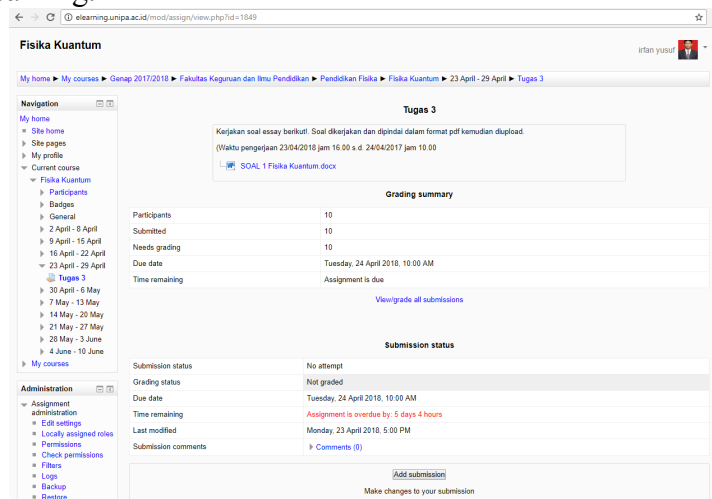


Figure 2. Records of tasks completed by all students.

Students, in general, are actively involved in learning. Involvement is visible on each task was given that they can complete all the tasks and upload them directly through e-learning as in Figure 2. Each student can interact directly with e-learning account given as a class participant. Lecturers can directly provide an assessment of each task so that students can know the results of the assessment of the tasks they do. Learning through e-learning is very effective, and there is no limit between lecturers and students as well as students with whom they can interact in learning (Zhanga, et al., 2006). The use of e-learning can also create the independence of learners learn that they can perform activities to complete the task

independently through their respective accounts (J. K. Lee and W. K. Lee, 2008). Learning through e-learning can improve the thinking ability of learners because they are expected to seek and find themselves a concept (Saadé, et al., 2012; Muryani, et al., 2017)

Measurement of HOTS capability of students before and after learning through e-learning based on in quantum physics courses obtained the N-g value of 0.4 or is in the high category as shown in Table 3. This result shows that learning through STEM-based e-learning on the course of quantum physics is instrumental in improving students HOTS skills. HOTS demonstrate the learners' deep understanding of the learning material that has been studied (Tanujaya, 2016).

Table 3. The result of HOTS student ability test before and after STEM-based physics learning using e-learning media

	Pretest	Posttest	g	N-g	N-g Criteria
Average	33.3	72.0	38.8	0.7	High
Standard Deviation	13.4	40.4	21.1	0.3	

The effectiveness of learning through e-learning based on the STEM in quantum physics course on students HOTS capability is shown through the result of effect size test as shown in Table 4. The result of effect size calculation is obtained by 3.5 which shows that e-learning is effective in physics course quantum of students HOTS capabilities.

Table 4. Results of effect size testing to find out how much the effectiveness of learning through e-learning based on the STEM in the subject of quantum physics

Learning Outcome	Average	Standard Deviation	Effect Size	Category
Pretest	33.3	13.4	3.5	High
Posttest	72.0	20.4		

Table 4 also shows that the average of pretest and posttest learning outcomes of students has increased from $33.3 \pm SD 13.4$ to $72.0 \pm SD 20.4$. The improvement of learning outcomes indicates that the performed learning improves students HOTS capabilities, although the standard deviation of posttest high is 20.4. This is because there is one student with the same value when the pretest and the value are very low compared with other students who have increased. The low learning outcomes of students are due to lack of activity during learning and often do not follow lectures online. Student activity can be traced directly through the use of e-learning as each student has their account and is known when they are active (Blas and Fernández, 2009).

The result of normality test data obtained sig value. Pretest and posttest respectively are 0.025 and 0.007 less than 0.05 indicating that the data is not normally distributed. Homogeneity test results obtained sig value. 0.566 bigger than 0.05 indicating that the data is homogeneous. Based on the result of the prerequisite test, it is found that the data is not normal but homogenous so that the non-parametric testing technique is done through Wilcoxon test as in Table 5.

Table 5. Wilcoxon test results of HOTS capability of students before and after STEM-based physics learning using e-learning media

	N	Mean Rank	Sum of Ranks		Posttest - Pretest	
Negative Ranks	0 ^a	0.00	0.00	Z	-2.666 ^b	
Posttest - Pretest	Positive Ranks	9 ^b	5.00	45.00	Asymp. Sig. (2-tailed)	0.008
	Ties	1 ^c				
	Total	10				

Table 5 shows that in the aymp sig (2-tailed) for the 2-sided test is 0.008. Since the case is a one-sided test, the probability becomes $0.008/2 = 0.004$. Here comes the probability of below 0.05, then it can be concluded that the use of e-learning-based on STEM has a real effect on the ability to raise student HOTS. At the end of the study, perceptions were assessed on ten students to know their responses to the lessons learned. Student perceptions of learning using e-learning based on the STEM are shown in Figure 3.

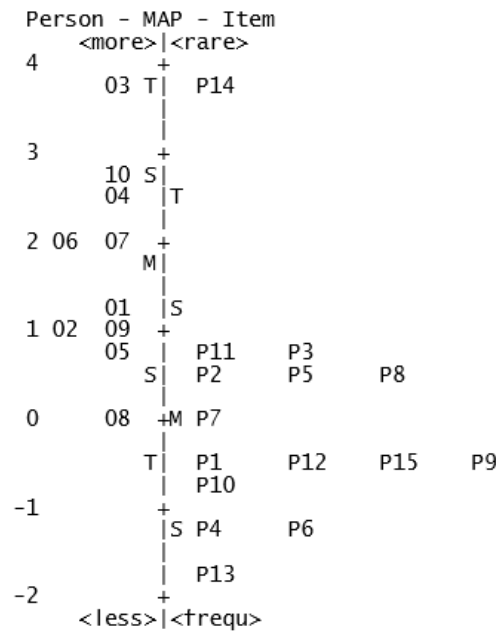


Figure 3. Student Perceptions of E-Learning Implementation based on the STEM on Quantum Physics Subject to HOTS Ability

Figure 3 shows that on the left map there are five students (03, 10, 04, 06, and 07) whose high ability rate is to approve all statement items in a given perceptual questionnaire except the P14 statement that is about the display of e-learning media that can see on the right map. This is because the display of e-learning media is an innate display of moodle programs provided by the Universitas Papua computer center which by default has been set up with a minimalist look. The minimalist look is due to the limited server of the Universitas Papua and also the consideration of large data capacity when accessed by users, but the view does not reduce the facilities provided in e-learning to support learning activities. The use of the Moodle Program as e-learning is perfect for online learning as it comes with a variety of exceptional features (Aydin and Tirkes, 2010; Limongelli, et al., 2011).

At the bottom left of the map, there is one student (08) with low abilities or the lowest level of approval compared to other students. The student also has a low HOTS ability compared to the others. This is because students do not regularly attend lectures and are often not active in online classes. Assessment of students perceptions generally agrees on the lessons learned. The use of e-learning media based on the STEM in quantum physics courses can improve the positive response of learners to the learning.

CONCLUSION

Implementation of STEM-based e-learning in quantum physics courses is instrumental in improving students HOTS skills. This can be seen based on the results of the N-gain test that is obtained results 0.7 (high). The effect size value is 3.5 (high), and the value of

Wilcoxon test probability is 0.004 (below 0.05), and the students perception is general learning well so it can be concluded that e-learning is effectively used in the quantum physics lecture and has the real effect to increase students HOTS capability. The study of quantum physics through the utilization of e-learning allows learners to be able to explore and find themselves a concept. A wide variety of reference books and instructional materials are presented directly and accessible whenever and wherever they are both inside and outside the classroom. All students are actively involved in learning. Learning through e-learning is very effective, and there is no limit between lecturers and students. The implementation of e-learning based on the STEM in quantum physics course could be used as one of the references to develop students HOTS capability.

ACKNOWLEDGMENTS

Our thanks to the Dean of the Fakultas Keguruan dan Ilmu Pendidikan, Universitas Papua for their help and support during the implementation of the activities. The author also expressed gratitude to the head of Computer Center in Universitas Papua for his help during the use of e-learning.

REFERENCES

- Wahyuni, D. S. and Zainnuri, H. (2017). Boostering Students' Life Skill through IT Based Project Learning. *Advances in Social Science, Education and Humanities Research (ASSEHR)*, 158(2017), 319-328.
- Yusuf, I. and Widyaningsih, S. W. (2018). Profil Kemampuan Mahasiswa dalam Menyelesaikan Soal HOTS di Jurusan Pendidikan Fisika Universitas Papua. *Jurnal Komunikasi Pendidikan*, 2 (1), 42-49.
- Suryani, A. (2017). I am an Old Car, My Engine is not Powerful Anymore A Senior Teacher's Voice on His ICT Learning, Obstacles and Its' Implications for Teachers' Development. *International Journal of Pedagogy and Teacher Education (IJPTE)*, 1 (2), 174-188.
- Yusuf, I. and Subaer, S. (2013). Pengembangan Perangkat Pembelajaran Fisika berbasis Media Laboratorium Virtual pada Materi Dualisme Gelombang Partikel di SMA Tut Wuri Handayani Makassar. *Jurnal Pendidikan IPA Indonesia*, 2 (2), 189-194.
- Yusuf, I., Widyaningsih, S. W. and Purwati, D. (2015). Pengembangan Perangkat Pembelajaran Fisika Modern Berbasis Media Laboratorium Virtual berdasarkan Paradigma Pembelajaran Abad 21 dan Kurikulum 2013. *Pancaran Pendidikan*, 4 (2), 189-200.
- Iksan, Z. H. and Saufian, S. M. (2017). Mobile Learning: Innovation in Teaching and Learning using Telegram. *International Journal of Pedagogy and Teacher Education (IJPTE)*, 1 (1), 19-26.
- Gunga, S. O. and Ricketts, I. W. (2007). Facing the Challenges of E-learning Initiatives in African Universities. *British Journal of Educational Technology*, 38 (5), 896-906.
- Proudfoot, D. E. and Kebritchi, M. (2017). Scenario-Based E-learning and STEM Education: A Qualitative Study Exploring The Perspectives of Educators. *International Journal of Cognitive Research in Science, Engineering and Education (IJCRSEE)*, 5 (1), 7-18.
- Popovici, A. and Mironov, C. (2015). Students' Perception on Using E-learning Technologie. *Procedia - Social and Behavioral Sciences*, 180, 1514-1519.

- Tubaishat, A. and Lansari, A. (2011). Are Students Ready to Adopt E-learning? A Preliminary E-readiness Study of a University in the Gulf Region. *International Journal of Information and Communication Technology Research*, 1 (5), 210-215.
- Hake, R. R. (1998). Interactive-Engagement versus Traditional Methods: A Six-Thousand-Student Survey of Mechanics Test Data for introductory Physics Courses. *American Journal of Physics*, 66 (1), 64-74.
- Hake, R. (2002). Relationship of Individual Student Normalized Learning Gains in Mechanics with Gender, High-School Physics, and Pretest Score on Mathematics and Spatial Visualization. *Journal International Indiana University*, 1 (1), 22-34.
- Cohen, J. (1992). A power primer. *Psychological Bulletin*, 112 (1), 155-159.
- Boone, W. J., Staver, J. R. and Yale, M. S. (2014). *Rasch Analysis in the Human Sciences*. Springer Dordrecht Heidelberg, New York London, 2pp. 2-4.
- Gordillo, A., Barra, E., Gallego, D. and Quemada, J. (2013). *An Online E-learning Authoring Tool to Create Interactive Multi-Device Learning Objects using E-infrastructure Resources*. 2013 IEEE Frontiers in Education Conference. Oklahoma City Oklahoma USA, pp. 1-7.
- Azis, A. and Yusuf, I. (2013). Aktivitas dan Persepsi Peserta Didik dalam Implementasi Laboratorium Virtual pada Materi Fisika Modern di SMA. *Berkala Fisika Indonesia*, 5 (2), 37-42.
- and Nunamaker, J. F. (2006). Instructional video in e-learning: Assessing the impact of interactive video on learning effectiveness. *Information and Management*, 43 (1), 15-27.
- J. Lee, J. K. and Lee, W. K. (2008). The Relationship of E-learner's Self-Regulatory Efficacy and Perception of E-learning Environmental Quality. *Computers in Human Behavior*, 24 (1), 32-47.
- Saadé, R. G., Morina, D. and Thomas, J. D. E. (2012). Critical Thinking in E-learning Environments. *Computers in Human Behavior*, 28 (5), 1608-1617.
- Muryani, C., Sarwono, and Nugraha, S. (2017). Importance Developing E-learning for High School Students In Sragen Regency, Central Java. *International Journal of Pedagogy and Teacher Education (IJPTE)*, 1 (2), 139-146.
- Tanujaya, B. (2016). Development of An Instrument to Measure Higher Order Thinking Skills in Senior High School Mathematics Instruction. *Journal of Education and Practice*, 7 (21), 144-148.
- Blas, T. M. and Fernández, A. S. (2009). The Role of new Technologies in The Learning Process: Moodle as A Teaching Tool in Physics. *Computers & Education*, 52 (1), 35-44.
- Aydin, C. C. and Tirkes, G. (2010). *Open source learning management systems in e-learning and Moodle*. IEEE EDUCON 2010 Conference, Madrid.
- Limongelli, C., Sciarrone, F. and Vaste, G. (2011). Personalized E-learning in Moodle: The Moodle LS System. *Journal of e-Learning and Knowledge Society*, 7 (1), 49-58.

The INNOMATTS: A Model of Mathematics Teacher Training Management

Mohammad ASIKIN¹ , Iwan JUNAEDI¹, Adi Nur CAHYONO¹

¹ Department of Mathematics, Faculty of Mathematics and Science, Semarang State University, Indonesia

Received: 20.06.2018

Revised: 20.09.18

Accepted: 15.12.2018

The original language of article is English (v.15, n. Special Issue, December 2018, pp.76-86, doi: 10.12973/tused.10259a)

ABSTRACT

The purpose of this paper is to analyze the impact of the INNOMATTS (Innovative Mathematics Teaching Study) Model on content knowledge and impact on pedagogical content knowledge related to the role of teacher. The research design is an adaptation of research and development research design. Data and information were obtained from Semarang Junior High School (JHS) Mathematics Teachers as trainees. Used data collection tool is questionnaire and test. The data were analyzed descriptively narrative and quantitative calculation. The results of the study and discussion are as follows: (i) In relation to the perception, only 27% of the teachers who think that the government training programs that have been followed so far there is a post-training follow-up program; 60% of the teachers found that they only participated in training if there were programs from the government; (ii) The effectiveness of the overall training model from before to after the model implementation of teacher competence has increased. the magnitude of the normalized average gain effectiveness before and after the model implementation is 0.62 (62%) in the moderate category; while the average effectiveness of the overall model characteristic is 75.35 is included in either category. Taking into account the effectiveness of the empirical model of both process and product as a whole, the overall effectiveness of pretest and posttest, as well as the results of the RPP assessment and its implementation, it can be concluded that the implementation of the model contributes to the improvement of professional competence of JHS Mathematics teachers in Semarang City.

Keywords: INNOMATTS, mathematics teacher professional competencies, professional development model, training model

INTRODUCTION

Many factors determine the quality of education. However, the quality of education is still in bounded with teachers' determination which identified by direct interactions from teachers straight to learners. Teachers who are in control of learning, determine the achievement direction of indicators and learning objectives. Good and superior education is highly dependent on quality, professionalism, performance and competence of the teacher. To produce qualified learners, require qualified teachers who have competence and high



dedication in carrying out their professional duties (Kunandar, 2007: 40). Podhorsky and Moore (2006) argued that educational reform should be interpreted as an effort to create programs that focus on improving teaching and learning practices rather than focusing solely on classroom design with teacher proof curriculum. Learning practices can only be changed through testing the teachers' ways in packing and carrying out learning. Therefore, coaching program of teacher profession is necessary. The teacher competence has been taken by the government in various ways. These efforts include education and training (in service training). However, the government's efforts to improve teacher competence through training do not give a significant impact on improving the quality of learning (Hendayana, (2007). There are two reasons why the training for teachers has not had an impact on improving the quality of learning: (a) the training is not based on real issues in the classroom, for example the same training materials are delivered to all educators without knowing their background (b) the training is only theoretical which is not able to be applied in the classroom learning (Hendayana, 2007). According to Suparlan (2006) and also Lie (2010), there is a little evidence of the impact of the teacher training on the quality of learning. In addition, the activities for teacher professions such as training, workshops, and seminars actually causes problems in schools because teachers leave their main task, namely teaching.

According to Burns (2011) professional development should refer to five things that have been known to help the development of good teaching: content, instruction, pedagogical content knowledge, knowledge of learning and development, and efficacy. Whereas effective development of professionals according to Burns (2011) should meet the followings: (i) implemented over a long period of time, (ii) sequential, (iii) differentiated based on teacher needs and reality, (iv) providing opportunities for teachers to see (v) help teachers plan and design their application in the classroom, (vi) provide practice and reciprocity to teachers, and (vii) have opportunities for revision. Other views related to professional development of teachers are given by the Asia Society (2010) through stating that a strong professional development system can be realized only in educational systems that do the following: (i) evaluating teachers on indicators providing formative feedback useful in improving teaching and on some indicators for overall performance evaluation, (ii) stimulating teachers in designing curricula, teaching, and assessment to align and strengthening teachers' understanding of how to achieve agreed standards. Bhawan (NCTE, 2009) argues that in every effort to strengthen the professional practice of teachers, every teacher should be viewed and respected as a professional. Including the training content and approaches, how the trainings are announced and how they are implemented. Professional teacher development programs should build and strengthen the identity of teachers as professional teachers and also establish and maintain relationships with the academic discipline of their interests in many cases.

To strengthen the professional practice of teachers, there should be a training model for mathematics teachers which contains solution for existing problems, innovation, independence, and sustainability characteristic in teacher training programs. The solution providing the characteristic implies that the training objectives should be based on finding solutions to the problems factually faced by the teacher and in the form of a bottom-up training model in addition to the needs and real problems of the math teacher in the field. So, the training can be a solution to teacher problems. The innovation characteristic of the training model refers to Patel's opinion (2011) that innovation in teaching mathematics can be diversified in terms of methods, pedagogic resources, and mastery of learning strategies. This suggests that innovative training models need to pay attention to innovations in mathematics learning including teachers' efforts to achieve learning mastery, applied methods and learning strategies and use of pedagogic resources such as developing a learning media, building classroom activities based on student activity and developing good teaching materials

according to curriculum demands. While the independence characteristic means that training activities do not only rely on the existence of training programs from the government, but training activities can be initiated by a group of teachers in a particular region or teachers of mathematics subjects that are collected in an educational foundation as well. The training model should also have the sustainability characteristic which means that there is further assistance both in group and in individual after the training, as well as further training programs.

INNOMATTS Training Management: A Conceptual Framework

According to Yayat (2007) the theoretical cycle of training management is "Systematic Training Approach". This approach is related to the procedure of managing the training, which begins with the existing problems that may interfere the achievement of the expected objectives, up to the evaluation and follow-up in accordance with the problem-solving efforts through training. General and hierarchical training management procedures contains ten steps: Step 1: Identifying and Analysing Training Needs, Step 2: Testing and Analysing Positions and Duties, Step 3: Classifying and Determining Training Participants, Step 4: Defining Training Objectives, Step 5: Designing the Curriculum and Training Syllabus, Step 6: Planning Training Program, Step 7: Preparation and Development of Terms of Reference (TOR), Step 8: Implementing the Training Program, Step 9: Evaluating Training Program, and Step 10: Follow Up Training. The quality of the training depends on the management of the training such as on the accuracy of selecting the training materials, the quality of the resource, the training method and the evaluation. An analysis of training needs as a stage in the preparation of programs related to the types, procedures, models and training techniques needs to be done in training management. The procedure begins on analysing existing tasks/functions and requirements to fulfil the functionality qualifications. After that, it continues with looking for a solution of training type including a material to be presented and appropriate training methods to meet the required qualification types related to the expertise's skills and areas. At the end of the training, it should be evaluated to determine the effectiveness of changing or improving the behaviour of trainees in an effort to improve performances.

Russell in Sulistiyani & Rosidah (2003) explained that training stages include: 1) need assessment, which aims to gather information to determine whether training programs are needed or not, 2) development of training programs, which aims to plan the training environment and training methods needed to achieve the training objectives, 3) the evaluation of the training program, which aims to assess whether the training has achieved the expected objectives. The stages of the training program are designed carefully according to the needs. The benefits of training-need analysis are as the basis for formulating training programs. Goldstein and Ford (2002: 327-328) proposed the model of training-process cycle as shown in Figure 1. According to Davies (in Rosidah, 2003) training management is closely related to the activity trident, i.e. (a) planning, (b) implementation, and (c) evaluation. Depending on the used approach, three components can be developed into several activity steps. The training management procedures in the INNOMATTS (Innovative Mathematics Teaching Study) model are:

- Identify and analyze the needs of Junior High School (JHS) / Sekolah Menengah Pertama (SMP) mathematics teachers in an effort to improve their competence
- Analyzing various competency views of the mathematics teachers and their tasks
- Classify the requirements of trainees and assign trainees
- Formulate training objectives (stated in INNOMATTS implementation manual)

- Design a training syllabus (included in the INNOMATTS implementation manual)
- Plan the training program according to the flow and mechanism set out in the manual
- Compiling the Terms of Reference Training (stated in the guidebook)
- Implement INNOMATTS model training program
- Evaluate the implementation of each activity at each level and a thorough evaluation of the implementation of the INNOMATTS model
- Provide follow-up activities of training results

The first step is assessment and analysis of training needs in managing the training program. As a result of various changes these training needs can be categorized into two types such as current needs and future training needs,. On the other hand, this step is added by the identification of the resources available to enable the problem to be solved.

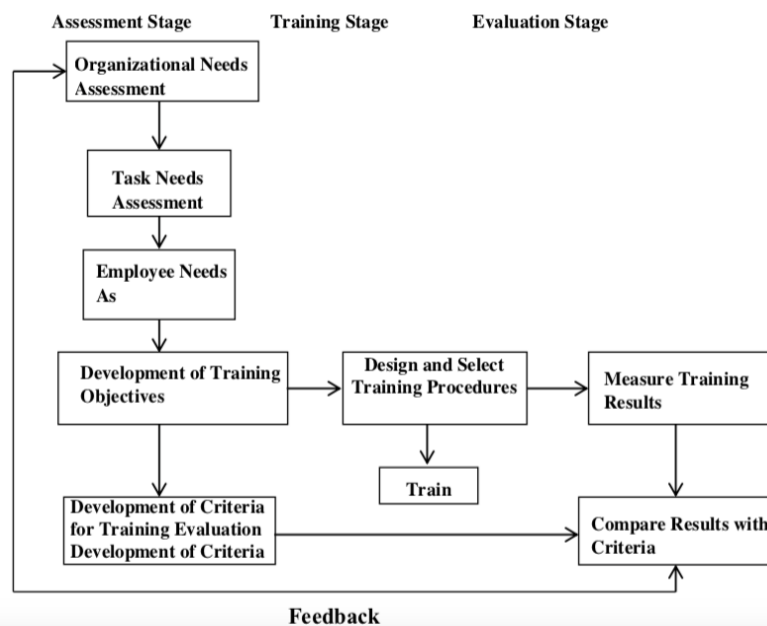


Figure 1. Model of the training process (Goldstein dan Ford, 2002)

Referring to the various description above then developed a model of training for Math teachers called INNOMATTS model. One of the theoretical underpinnings of model development is Burn Theory (2011) on the importance of a teacher training model for the development of qualified professionals. Burns (2011) provides the following characteristics of high-quality professional development of teachers: (1) developing a competency base that focuses on helping teachers develop knowledge, skills, attitudes, and dispositions to improve teaching, (2) basing on the understanding of teacher needs and work environment (3) focusing on the teacher's content and pedagogical skills, (4) appropriately modelling the behaviour of teachers in the classroom and including opportunities for practice, research, and reflection, (5) integrating in the workplace of educators during and ongoing schooling over time, (6) basing on a sense of collaboration and collaboration among teachers as well as between teachers and principals to solve important problems related to teaching and learning, (7) building a professional learning community (the technical and social support provided by this community can help to overcome stagnation and help teachers make complex changes). In addition to providing characteristics to enable professional development of qualified teachers, Burns (2011) also provides indicators for effective professional development: (i) implemented over a long period, (ii) sequential, (iii) differentiated based on teacher needs, (v) to help teachers plan and design their application in the classroom, (vi) provide training and reciprocity to teachers, and (vii) have opportunities for revision. In addition to referring to

Burn (2011) theory, several professional-teacher-development models that also inspire and provide a theoretical basis in developing INNOMATTS models are: (1) Reflection Connection Cycle model (Taylor, 2011), (2) Problem Solving Cycle model (Jacobs, 2007), (3) model of Rogers (2007), (4) Teacher Professional Development model (Hooker, 2011), (5) Lesson Study model (Lewis et al, 2003, 2004) and (6) Based Training (Pattanida, 2004).

According to Rogers (2007), mathematics teachers need time to implement learning changes in their classes and critically reflect changes that occur in student learning. This process also requires the support of mathematics learning experts in the area who participate in providing input. Finally, if the change in inclass treatment brings a positive or negative impact on student learning outcomes, then changes in teacher beliefs and attitudes will also occur. The circular model is compatible with the PSC (Problem Solving Cycle) model of Jacobs. Jacobs (2007) who said the mathematical-profession-development model needed to be carried out repeatedly with a long-term approach to support teacher learning/training. One iteration of the PSC consists of three interrelated workshops where teachers share their pedagogy and mathematics experience. The PSC model is designed to be implemented by a facilitator. Facilitators can come from more knowledgeable teachers, math trainers, department directors, education specialists, or other teacher educators. In the model, group meetings in clusters are in line with the RCC (Reflection Connection Cycle) structure in a professional development program that consists of two important components (1) group meetings and (2) assignments both in class and home tasks. According to Zeichner and Listen (2011) as researchers and inventors of the RCC model, the group meeting and assignment process is designed to give teachers an opportunity to get a picture of a shared-knowledge and support the relationship between their own assignments and teaching. The core components of each group meeting include classroom video review, discussion of assignment, sharing of applied learning, and creating new lessons. The results of the 2011 CIMT (Center for Innovation in Mathematics Teaching) study entitled "International comparative study in mathematics teacher training" recommended that mathematics teacher training should take into account: (a) math skills of trainees, (b) duration of training, (c) the balance between theory and practice, and (4) the role of tutors from universities

Based on the above basic principles, the characteristics of the INNOMATTS training model are as follows: (1) Solution for existing problems: The training program is oriented to the needs and problem solving faced by Junior High School Mathematics teachers in learning, (2) Independence: The training program can be implemented with or without program support and government funding. Initiation can start from the Mathematics teacher community either in school, foundation or MGMP (Teacher Education Consensus Points), (3) Innovation: The innovative understanding of the INNOMATTS model is seen in two concerns such as the training model and on the content or training materials and (4) Sustainability: There is further assistance both individually and individually after the training as well as further training programs. The implementation strategy of the INNOMATTS training model or the means used to achieve the stated objectives is as follows: (1) the training can be carried out as part of routine scheduled activities in an organization or association of Mathematics teachers such as MGMP of Mathematics Junior High in a region, 2) the training model is designed and implemented in the cycle model (application of the Deming PDCA/Plan-Do-Check-Act cycle), with activities based on group work and individual work. For example, group-based activities (activities undertaken in clusters) are teachers together with other members in a cluster planning lesson plan, and followed up by doing classroom learning, one of the teacher as the teacher model while the other teachers observing and observation results discussed together again. Furthermore, each teacher performs an action in each school without being observed by peers, and so on over and over (in accordance with the program designed

thoroughly), (3) Assistance by the tutor during the training process, both in activities in the cluster and individual activities. The purpose of this paper is to analyse the impact of the INNOMATTS Model on content knowledge and impact on pedagogical content knowledge related to the teacher's role.

METHODOLOGY

a) Research Design

The adopted research design is an adaptation of Research and Development (R&D) research design from Gall (2007). The first step of the study is an exploratory study that includes literature review and direct-observation of data sources to obtain data on teachers' perceptions and expectations about training activities. The results of the exploratory study are supported by the deepening of the literature review and informal discussions with teachers as well as with experts. Those are used as the basis for the formulation of conceptual models which subsequently developed into hypothetical models. The next step is a model development activity in the form of formative evaluation. Formative evaluations in the development of this model include validity, practicality and effectiveness.

b) Data Collection

Data and information were obtained from the respondents who are Junior High School Mathematics teachers in Semarang City selected as I trainees. Data used collection tools are questionnaire and test. Questionnaires were used to reveal the perceptions and expectations of the trainees on the training activity and training management while the tests were used to determine the impact on content knowledge and impact on pedagogical content knowledge related to the teacher's role. The instrument of exploratory study was developed based on the content outline that was compiled referring to the study of theory and government documents. Test was conducted to fulfil the empirical validity of the instrument. Data are classified by type and developed-model components.

c) Data Analysis

The data were analysed descriptively narrative and quantitative calculation. The hypothetical model was developed from a conceptual model with reference to the exploratory results as well as the deepening of various theoretical and discussion studies. The hypothetical model of the INNOMATTS model is validated using the Delphi technique. This technique is used as validation because it has two advantages that have the ability to accommodate every individual's subjective opinion and allow free expression of opinion which has no effect of domination. In this research, expert validation is done in two stages. The experimental empirical model is intended to determine the practicality and effectiveness of the model. The practicality of the model is indicated by the suitability of model implementation in the field with the model, while the effectiveness is indicated by the conformity of the objectives with the results of the model implementation. The test subjects in the development of the training model are 30 Junior High School Mathematics teachers in Semarang City from public and private schools. The thirty teachers are divided into 5 clusters in each consist of 6 teachers.

The purpose of the test is to determine the practicality and effectiveness of the model. In accordance with the test purpose, the test to see the effectiveness of the model is done with one test. This test is conducted for the purpose of detecting any possible change in teacher competency before and after training using the model. The design of the test is One Group Pretest - Posttest or experimental design before-after (Sugiyono, 2010). Tests are conducted through several stages. In general, these stages are the preparation stage, the implementation stage of the model, the analysis stage of the assessment of the model implementation, and the

preparation stage of the test report. The preparation stage is the stage of checking and preparation of various instruments that have been arranged as well as a means of assessing the success of model implementation. Implementation stage of the model is the beginning of implementing the program in accordance with the structure of the designed program. The plan covers each activity (classical activity/IN, and cluster and class activity/ON) and Review (R) activity both in class and in cluster repeatedly according with the groove model. The training is planned cyclically starting from the class or large group, clusters and individual activities repeatedly.

Table 1. *Impact on pedagogical content knowledge related to the teacher's role*

Characteristics	Indicators	Effectiveness (%)	Effectiveness of Each Component (%)
Solution for Existing Problems	Ability of the training activities in helping to overcome the problems faced by teachers	62.17	75,19
	The suitability between the success indicators of the training program and the needs of the mathematics teachers in the field	78.83	
	The preparation of the training program takes into account the needs / problems of the math teacher	80.92	
	Beneficial for the trainees	70.83	
	Unlike the previous model implemented	73.63	
Inovation	Training activities optimize the role of external resource persons	74.75	76,10
	The implementation of the training activities was completed by creative and innovative activities.	73.25	
	Training activities follow the development trend of learning	77.79	
	Training activities are easy to implement independently	76.33	
Independence	There are no obstacles faced in implementing the model independently	72.17	74,25
	Not implemented because it is difficult to organize the activity stage	74.25	
Sustainability	There is an evaluation to see the effects of plans and training outcomes on the parties concerned	80.75	75,54
	There are programs and implementation of post-training follow-up programs	70.33	

Based on the above table, the average of overall effectiveness is found to be 75.35 included in good category.

The results of the assessment based on the training management namely the suitability between the steps of activities undertaken at each stage and the steps of the model shown that: (1) in the planning stage of 97.5%; (2) on the implementation stage of 77.5%, and (3) at the evaluation measures of 65%. The average implementation of training activities in accordance with the steps of the model is 80%. Thus it can be said that the INNOMATTS Model is practical. Assessment of the effectiveness of INNOMATTS Model on the improvement of teacher competence is based on (i) the result of the assessment of the Lesson Plans (RPP) which is the average of the assessment by the first assessor is 77.46, while the average assessment of the second assessor is 77.97, so that the average the total is 77.72. These results indicate that the ability of teachers in INNOMATTS trainees in arranging the RPP included in good category, (ii) the results of the assessment of the implementation of the teaching namely average assessment by the first assessor obtained by 77.35 while the average assessment of the second assessor is 80.34, so the overall average is 78.85. These results indicate that the ability of INNOMATTS trainees in implementing the lesson plan is included in good category, (iii) the result of teacher professional competence test (UKG) before the

implementation of the INNOMATTS model is obtained 64.45, while the competency test after the implementation of the completed model is obtained average 81.30. The effectiveness of the overall training model from before to after the implementation of the model on the professional competence of teachers increased. The average gain normalized of the professional competence of teachers before and after the implementation of the model was 0.47 (47%) with the medium category. While the effectiveness of INNOMATTS overall training model from before to after model implementation of teacher competence, there is an increase. The average gain normalized of the effectiveness before and after the implementation of the model for teacher competence was 0.62 (62%) in the medium category. The effectiveness of the Model on the implementation of the Model characteristics for the solution of existing-problem component is 75.19; the innovation component of 76.10; the independence component is 74.25 while the sustainability component is 74.25. The average overall effectiveness is 75.35 in the good category.

Related to the expectations and needs of teachers on the existence of training that can be stated that teachers of SMP Mathematics in Kota Semarang need innovative training which follow the demands of the time, as well as training materials in accordance with the needs of teachers. During this time, they would attend training only if there were programs from the government. Teachers also expect academics and other professionals to train them. The involvement of academics in teacher training will be more manageable and organized if the training provider is the teacher community itself, thereby reducing the involvement of others as it can independently be managed by the teacher community.

The expectations and needs of the teachers will be more easily met if there is a community of teachers who initiates the training of teachers with materials that match the needs and problems they face. The INNOMATTS model can be an option because the characteristics of this model are solution for existing problems and independence meaning that the teacher community can independently coordinate the training by involving experts from the universities.

Teacher perceptions related to the training management that had been followed previously obtained data that less than 60% mathematics teachers in Semarang City who had attended, knowing the training plans, training objectives, training support elements, and management activities that occurred during the training process. Associated with the evaluation, only about 50% of teachers who think that there is evaluation during training program and the evaluation process to see the effects of training plans and results. What strikes most from teachers' opinion is that 73% of teachers think that the training they attend does not provide post-training follow-up programs. This result is in line with the findings of Ardhana (2003) which stated that there has not been found operational and practical training in educational praxis. The results of the exploratory study in this study also support the findings of Hendayana (2007), Suparlan (2006) and Lie (2010) who said that the training did not have a significant impact on the improvement of learning quality.

The first stage of expert validation results, obtained data that the percentage of assessment in all components are above 70% which means the items on the components are good. Based on the validation of the first stage is actually a model can already be said valid. But there are some suggestions for improvements provided by validators that are critical to model improvement.

Completion of the model is done by taking into account the justification and suggestion of refinement given by the expert. The model and its guidance are thoroughly reviewed so that it becomes clearer and easier for experts to judge. Revisions or improvements to the model, guide, or instrument are used in second stage model validation. Expert validation results of the model in the second stage showed that of the 34 grains of the all model components assessed, obtained more than 70 percent. The results of Kruskal Wallis

hypothesis test showed that there is no significant difference in the assessment given by the academia, professional trainers and practitioners. The above test results indicate that there is no component that must be revised or refined, it means that there has been agreement of the second stage expert validation.

The result of formative evaluation of empirical model implementation in the test to measure the practicality and effectiveness of the model shows that the process stages of INNOMATTS empirical model implementation is done according to the model and guidance. There are only some stages that the implementation is not optimal yet. There is a very interesting finding to consider as a refinement of the final model. Firstly, the implementation of the activities has implemented the right strategy that the participants are actively discussing, learning while working, intensive group approach and implementing the principles of Plan-Do-Check-Act. Although the participants' little inconvenience (such as designing RPP) were expressed. This is due to their relatively unequal experiences and abilities. Therefore, it is countered by tutorial strategy and multiplying to give example so that finally the implementation in general become conducive. Secondly, the leadership role of the cluster leader as the motivator and facilitator, raises the sympathy of the participants, supports the smooth implementation of the training, and gives a positive impact on the trainees' sustainability and comfort.

Associated with the results of formative model assessment, namely the execution of model characteristics, the measurement results show that overall effectiveness was quite high that was equal to 75.35. The effectiveness of the overall INNOMATTS training model from before to after the implementation of the model on teacher competence was increased. The magnitude of the average gain normalized effectiveness before and after the implementation of the model for teacher competence was 0.62 (62%) with high category. All components / indicators demonstrate good performance as a direct or indirect influence of the implementation of the INNOMATTS empirical model indicated by the magnitude of effectiveness achieved. Direct influence can be explained that the increase of magnitude occurs due to the activities carried out directly related to the component / indicator such as seen in the indicators of learning activities in the classroom that educate, communicate with learners, and master materials, structures as well as mathematical concepts.

CONCLUSION

Based on the results of research and discussion described above obtained the following conclusions. In relation to the perception, the expectation and needs of teachers related to training is only 27% of teachers who think that the training that followed so far there is a post-training follow-up program; 60% of teachers found that they only participated in training if there were programs from the government; 75% of teachers thought about the need for the suitability between training materials and the needs in the field. 97.5% of teachers expect innovative and up-to-date training; 92% expect the presence of colleagues, supervisors, academics and professionals involved in teacher enhancement training activities; 55% of teachers expect an evaluation of the training conducted during the training process not only at the end of the training.

The result of model development related to practicality of the model based on suitability between training implementation and model steps is 80%, while model effectiveness toward improvement of teacher professional competence with indicator ability to develop learning tools is equal to 77,72 with good category; for learning activity indicator of 78,85 with good category; while the result of professional teacher competency test obtained the average gain normalized professional competence of teacher before and after implementation of model is equal to 0,47 (47%) with medium category; the effectiveness of the overall INNOMATTS

training model from before to after the model implementation of teacher competence has increased; the magnitude of the normalized average gain effectiveness before and after the model implementation is 0.62 (62%) in the medium category; while the average effectiveness of the overall model characteristic is 75.35 which is included in good category.

Taking into account the effectiveness of the INNOMATTS empirical model of both process and product as a whole, the increase of overall gain effectiveness of pretest and posttest, as well as the results of the RPP assessment and implementation indicate that the implementation of the INNOMATTS model contributes to the improvement of professional competence of Junior High School Mathematics teachers in Semarang City. The solution providing the characteristic implies that the training objectives are based on finding solutions to the problems factually faced by the teacher and in the form of a bottom-up training model in addition to the needs and real problems of the math teacher in the field. So, the training is a solution to teacher problems and contains solution for existing problems, innovation, independence, and sustainability characteristic in teacher training programs. As an impact, the professional practice of teachers is strengthened.

ACKNOWLEDGEMENTS


The research reported here was supported by a grant from Kementerian Riset, Teknologi, dan Pendidikan Tinggi RI through 'Skema Penelitian Hibah Bersaing tahun 2013 dan 2014'.

REFERENCES

- Anthony, G., & Walshaw, M. (2007). *Effective pedagogy in pāngarau/Mathematics: Best evidence synthesis Iteration [BES]*. Wellington: Ministry of Education.
- Ardhana, W., Kaluge, L., & Purwanto, P. (2005). Pembelajaran Inovatif untuk Pemahaman dalam Belajar Matematika dan Sains di SD, SLTP, dan di SMU. *Laporan penelitian hibah pascasarjana Angkatan I tahun III*. Direktorat Penelitian dan Pengabdian pada Masyarakat. Ditjen Dikti. Depdiknas.
- Asia Society. (2010). *Learning from the world*. New York.
- Burns, M. (2011). *Distance education for teacher training: modes, models, and methods*. Washington, DC: Education Development Center, Inc.
- Butler, D., & dan Leahly, M. (2003). *The TeachNet Ireland project as a model for professional development for teacher*. Dublin: St Patricks College of Education, Duplin City University.
- Cerbin, W., & Kopp, B. (2006). Lesson study as a model for building pedagogical knowledge and improving teaching. *International Journal of Teaching and Learning in Higher Education*, 18(3), 250 – 257.
- Ditjen PMPTK. (2010). *Panduan Penilaian Kinerja Guru*. Jakarta: Pusbangprodik.
- Ditjen PMPTK. (2010). *Pedoman Pengelolaan Pengembangan Keprofesian Berkelanjutan (PKB)*. Jakarta: Pusbangprodik.
- Gall, M. D., Gall, J. P., & dan Borg, W. R. (2007). *Educational Research: An Introduction, 8th ed.* New York: Pearson.
- Guskey, T. R., & Jung, L. A. (2009). *Grading and Reporting in a Standards-Based Environment: Implications for Students with Special Needs*. Paper presented at American Education Research Association Conference.
- Hendayana, S. (2007). *Lesson Study: Pengalaman IMSTEP-JICA*. Bandung: UPI Press.

- Hill, H. C., Ball, D. L., & Schilling, S. G. (2008). Unpacking pedagogical content knowledge: Conceptualizing and measuring teachers' topic-specific knowledge of students. *Journal for Research in Mathematics Education*, 39(4), 372-400.
- Hooker, M. (2011). *Models and Best Practices in Teacher Professional Development*. Online. Available from infoDEV.
- Jacobs, J., Borko, H., & Roberts, S. (2009). *The problem solving cycle: A model of mathematics professional development*. Tersedia di http://www.colorado.edu/education/staar/documents/PSC_NCSM_013007_FNL.pdf [diakses 21 Januari 2012].
- Kristin L. (2011). *Preparation of Effective Teachers in Mathematics*. National Comprehensive Center for Teacher Quality. USA.
- Lewis, C. (2006). *Lesson study in North America: Progress and challenges*. Tersedia pada <http://www.lessonresearch.net/res.html>. [Diakses 15 Agustus 2007].
- Lewis, C., Perry, R., & dan Hurd, J. (2004). A Deeper Look at Lesson Study. *Academic Search Premier*, 61(5), 18-22.
- Lewis, C., Perry, R., Hurd, J., & O'Connell, M. P. (2002). *Lesson study comes of age in North America*. Tersedia pada [http://www.lessonresearch.net/LS_06 Kappan.pdf](http://www.lessonresearch.net/LS_06_Kappan.pdf). [Diakses pada tanggal 15 Agustus 2007].
- Mark, J., Gorman, J., & Johannah, N. (2009). Keeping teacher learning of mathematics central in lesson study. *NSCM Journal*, 12(1), 3-11.
- Marsigit. (2007). Mathematics teachers professional development through lesson study in Indonesia. *Eurasia Journal of Mathematics, Science and Technology Education*, 3(2), 141-144.
- National Council for Teacher Education (NCTE) (2009). *Towards preparing professional and human teacher*. Published by Member-Secretary, National Council for Teacher Education Wing II, Hans Bhawan, 1, Bahadur Shah Zafar Marg, New Delhi-110002.
- Patel, R. (2011). *Innovations in Teaching Mathematics*. Waymade College of Education.
- Pattanida P. (2004). *School-Based training for in-service teacher development: atrategy for the succes of learning reform in Thailand*. Paper in the Fourth Scrutinizing Committee of the Council Minister.
- Penso, S. (2002). Pedagogical content knowledge: How do student teachers identify and describe the causes of their pupils' learning difficulties? *Asia-Pacific Journal of Teacher Education*, 30(1), 25-37.
- Rogers. P. (2007). *Teacher professional learning in mathematics: An example of a change process*. Proceeding of 30th annual conference of Math Education Research Group Of Australasia MERGA Inc.
- Saad, N. S. (2008). *Teaching mathematics in secondary schools: theories and practices*. Perak: Universiti Pendidikan Sultan Idris (UPSI).
- Sugiyono, S. (2010). *Metode Penelitian Pendidikan (Pendekatan Kuantitatif, Kualitatif, dan R&D)*. Bandung: Alfabeta.
- Taylor, E.V. (2011.) *Supporting children's mathematical understanding: profesional development focused on out-of-school practices*. *Journal Math Teacher Education*, 15(4), 271-291.
- Volker, U. (2010). Systemic Innovations of Mathematics Education with Dynamic Worksheet as Catalysts. *Proceedings of CERME 6 page 1280-1289*. Lyon France INRP 2010.
- West, L., Hanlon, G., Tam, P., & Novelo, M. (2007). Building Coaching Capacity Through Lesson Study. *NSCM Journal*, 1(1), 26-33.

Science Teachers' Practical Knowledge of Inquiry-Based Learning

Fatih NGAISAH¹ , Murni RAMLI², Puguh KARYANTO³, Nur Faradilla NASRI⁴,
Lilia HALIM⁵

¹ Biology Education Department, Faculty of Teacher Training and Education, Universitas Sebelas Maret, Indonesia

² Dr, Biology Education Department, Faculty of Teacher Training and Education, Universitas Sebelas Maret, Indonesia

³ Dr, Biology Education Department, Faculty of Teacher Training and Education, Universitas Sebelas Maret, Indonesia

⁴ Faculty of Education, National University of Malaysia, Malaysia

⁵ Prof, Faculty of Education, National University of Malaysia, Malaysia

Received: 20.06.2018

Revised: 20.09.18

Accepted: 15.12.2018

The original language of article is English (v.15, n. Special Issue, December 2018, pp. 87-96, doi: 10.12973/tused.10260a)

ABSTRACT

Science teachers' practical knowledge of inquiry-based learning influence their beliefs about science teaching and learning. The Indonesian Curriculum released in 2013 has required teachers to teach science via inquiry-based approaches. In fact, some previous studies have found that teachers have difficulties in practically implementing the requirements suggested by the curriculum. It is believed that teachers' practical knowledge may influence their real teaching practices. This research aimed to analyze how teachers employed their practical knowledge in teaching inquiry-based science by selecting an appropriate type of inquiry in science topics. 105 science teachers purposefully drawn from the regular meeting of Science Teachers Association of Surakarta City in February 2017 voluntarily participated in the survey. A nine-item questionnaire originally developed by W.W. Cobern et al (2104) was administered to measure the most appropriate type of inquiry in various science topics. The teachers' options represent their practical knowledge of inquiry-based learning. It is expected that teachers will choose the best appropriate type of inquiry focusing on student's autonomy, i.e an open inquiry. The results showed that the teachers differently interpreted the inquiry-based learning. Teachers mostly used guided-inquiry (32.8%) and open-inquiry (32.08%) to teach the science topics in the questionnaire. It was elicited that 12.17% of them selected didactic direct inquiry, whilst 22.65% of them chose active direct one. It is recommended that future studies should handle the results of the current study to appropriately formulate in-service curriculum and education for science teachers.

Keywords: Inquiry-based learning, practical knowledge, science



INTRODUCTION

Science teaching and learning has recently focused on meaningful and contextual learning (Ultay & Calik, 2012, King & Henderson, 2018). That is, learning scientific concepts needs to be linked with the real-life issues or phenomena. Contextual learning gives a chance for students to interpret phenomena, experiment, and inquiry scientific approaches in understanding science concepts (Chinn, 2007). To promote meaningful and contextual learning, inquiry-based learning is recommended as one of the promising methods to understand science concepts properly.

Teachers' practical knowledge of the inquiry-based learning show their capabilities on implementing the inquiry-based learning as well as their comprehensive understanding of student's learning quality on the importance and benefits of the inquiry-based learning. Teacher's practical knowledge helps him to construct his conception of science and to learn about how to teach specific science topic(s) (Ratinen, Viiri, Lehesvuori & Kokkonen, 2015).

Teachers are expected to improve their professional skills by conducting proper pedagogical strategies for effective teaching (Drago & Mih, 2015). Because teachers have to use content knowledge, experimentation skills, and pedagogical knowledge, they need adequate skills to make and implement their lesson plans through pedagogical content knowledge (PCK) (Cobern, Schuster, Adams, Skjold & Mugaloglu, 2014). PCK is the benchmark to assess teachers' specific competencies and abilities portraying how to be a good teacher (Fernandez, 2014).

Teachers sometimes stumble in properly conducting the inquiry-based learning due to lack of practical knowledge and/or practical experience with the inquiry process (Crawford, 2000). In view of Adofu (2017), the inquiry-based learning is relatively inadequate in practicum, because teachers possess limited knowledge of inquiry concepts and processes. Therefore, to develop more effective and efficient practices of the inquiry-based learning, teacher should be equipped with ample skills and knowledge of the inquiry. Since teachers play a crucial role in the teaching and learning processes, their practical knowledge of the inquiry-based learning should be elaborated to drive their students to accomplish the learning goals. Teacher's practical knowledge of the inquiry-based learning may give students a chance to improve students' thinking skills and experiences through inquiries process or science process skills (Castro & Moralez, 2017).

Teachers' high expectations make learning activities more effective and meaningful (Bhengu & Mthembu, 2014). In the inquiry-based learning, teachers act as the bridges to connect their own students with the learning contents to achieve the learning goals. Teachers' conceptions of the inquiry are associated with their teaching practices which will develop their students' competencies/abilities (Wang & Jou, 2016). To successfully support the inquiry-based learning at science classes, science teachers should effectively manage the students' learning activities, look for the need(s) of each action, reconfigure their classes, and prepare better instruction (Harris & Rooks, 2010; Feyzioglu, 2015). Moreover, teachers are required to master the basic knowledge of the inquiry-based learning, particularly planning the learning design, students' activities, and developing the appropriate assessment. The effective learning design and assessment may assure the students' achievements throughout various student responses and their experiences or psycho-social backgrounds (Hong & Lawrence, 2011).

Various ideas on categorizing the inquiry process in the class are available in the related literature. Tafuya, Sunal and Knecht (1980) divided inquiry into four levels: confirmation inquiry (level 1), structured inquiry (level 2), guided inquiry (level 3), and open inquiry (level 4). Those levels are distinguished from each other based on teacher responsibility and student activities in three main stages, i.e., stating or identifying the problem, selecting the procedure,

and formulating the solution. In a similar vein, Cobern et al. (2014) formulated the similar inquiry types (see Table 1).

Teacher is expected to select the open inquiry as the most appropriate model to nurture students' understanding, abilities and autonomies of science concepts. The inquiry-based learning is recognized as an alternative approach to enhance their autonomies (Sierens et al., 2009; Hartingset al., 2015; Silva & Galembeck, 2016). In the framework of open-inquiry, students independently explore the phenomena, generate the hypothesis, and design the experiment(s) to deeply test their hypothesis. Further, they are encouraged to collect and analysis data to formulate their conclusion(s).

Table 1. *Pedagogical understanding levels of the inquiry*

Basic Modes	Variants	Operational Descriptions
Science as the factual content knowledge	<i>Didactic direct</i>	Teachers directly provide and explain the content knowledge through examples and demos without student activities.
	<i>Active Direct</i>	Teachers directly provide and explain the content knowledge. Students verify teachers' explanations.
Science as the developmental products of the scientific inquiry process	<i>Guided inquiry</i>	Students explore the phenomena or ideas with teacher guidance.
	<i>Open inquiry</i>	Students explore the phenomena or ideas. Teachers facilitate the exploration procedure but they do not actively influence on their decisions or concepts.

(Adopted from: Cobern, Schuster, Adams, Skjold, Mugaloglu, Bentz, & Sparks, 2014)

The inquiry-based learning improves students' abilities to: (a) build the basic knowledge, (b) foster problem-solving skills, (c) interpret the phenomena, (d) explain the interconnection(s) between scientific concepts and facts, and (e) construct the prediction about what happens (Avsec & Kocijancic, 2014). Also, the inquiry-based learning promotes students to explore their abilities to think about the real-life situations. When students are confronted with various tasks and questions that need comprehensive answers or solutions, or require them to change their problem-solving methods, students are able to use their competencies. This regular process trains students to solve their daily life problems and prepares them for long-life learning (Alameddine & Ahwal, 2016). A combination of inquiry and content knowledge can improve students' knowledge through real-life-activities while building their conceptions (Buczynski & Hansen, 2010). The inquiry-based learning, as a part of science teaching and learning, aims to improve students' learning outcomes of science (Abd-el-khalick et al., 2004). Acting as scientists to learn science may also evolve their higher-order thinking skills (Comley, 2009).

This research aimed to identify the science teachers' practical knowledge of the inquiry-based learning. Further, it identified how the science teachers linked the type of inquiry with the certain science topics. It also detected whether the science teachers promoted their student autonomies via open-inquiry, which is seen as the most appropriate type of inquiry in science learning.

METHODOLOGY

The research design was a case study of introduction of digital teaching material to the social science teachers at junior high schools in Surakarta, Indonesia. Participants in this study were 47-48 years old. The number of participants were 40 social sciences teachers which were selected according to purposive sampling. Data was collected by interview form.

The interview form was developed by considering a conceptual framework that consists of 4 (four) main components of learning process. The first component is included aspects of the ability and performance of teachers. In this aspect, semi-open statements were used to reveal teacher perception on planning for the utilization of digital teaching materials. The second component is to uncover the potential use of digital teaching materials. The third component comprised the pedagogical and technical aspects to reveal the teacher perception on development of teaching materials in relation to the fluency and continuity of teaching and learning activities. The fourth component is about the use of ICT in the social science learning process. The authors emphasized Yin's (2009) framework of the three principle of data collection, which consist of the use of multiple source of evidence, create a case study database, and maintain a chain of evidence, to construct the validity and reliability of data collection tool and data collection procedure. The interviews conducted with purposive sampling according to educational background.

Data analysis was conducted by using coding and categorization on each of words or phrases in the interview form which were relevant to the purpose of this research. Through the coding and categorization, 32 statements were grouped into 4 (four) main components. Interactive analysis including data collection, data reduction and verification to find common patterns were used as data analysis method in this research. Triangulation of methods by interview and questionnaire. The interview through checking selected with the respective respondents to make sure the data is properly written in accordance with reality was used as data validation technique.

Research Design

Through a survey research method, 105 science teachers from the Surakarta Middle School Science Teachers Association Meeting held in February 2017 were purposively selected. A 9-item questionnaire concentrated on nine science topics (i.e., *temperature and solubility, role of chlorophyll in photosynthesis, animal classification, microbes, water characteristics, air is a matter, power and movement, static electricity, and, light and reflection*) in the middle school curriculum and included four-optional inquiry methods for each topic. The items were selected from the Pedagogy of Science Teaching Tests (POSTT 3 and 4) developed by William Cobern et al. at Michigan University (from <http://www.wmich.edu/science/inquiry-items/index.html>), and we have asked permission to do translation and some changes, regarding the name of the teacher with more common name for Indonesian and Malaysian students, and match the topics with the suitable grade in both countries. The optional answers were developed in regard to the types of inquiry proposed by Cobern et al.(2014), i.e. didactic direct, active direct, guided inquiry and open inquiry. Sample questions are presented in Table 2. The optional letters were set randomly, in order to reduce the possibility of respondents to guess. For example, according to Q4, the teachers are expected to choose A, as a high level of inquiry, while, for Q8, they are expected to opt C as a reflection of open inquiry.

Table 2. Examples of pedagogy assessment test and expected answers, adopted from *Pedagogy of Science Teaching Tests (POSTT)*

Questions	Didactic direct	Active Direct	Guided Inquiry	Open Inquiry
Q4. <i>Microbiology</i> Mr. Chong introduces the idea to grade nine students that microbes are minuscule living	D. In the early learning process, I will explain to the students what we will learn today	C. I will explain the microbe can be found almost everywhere in daily life. Then I will use the ideas from	B. I will ask students what conclusion can be drawn from their lists. Based on their ideas I will confirm the	A. I will praise students for their participation, then end the learning session by asking

beings live around us. He asks the students to make a list about the places they think they can and cannot find microbes. Students then read their lists and Mr. Chong writes them on the board.



Based on the aforementioned situation, please choose the alternative that most likely you do on this orientation stage? (POSTT 4-p.5)

before they involved in various learning activities.

their lists as to support the learning goal to connect the learning contents with students' ideas and daily life situation.

microbes can be found everywhere.

the students to write a short paragraph about where we can find the microbes.

Q8. *Static electricity*
Mr. Maniam taught grade seven students about static electricity. He only wants the students to experience those phenomena by observing some materials can produce static electricity better than others when rubbed to balloon. He brings several balloons and materials to be rubbed, such as wool, plastic bag, feather, glass, cabbage, and newspapers. He asks the students to rub each of the sample materials to the balloon, and test it how strong the balloon will be attached to the wall.



Think about how you will teach this topic. Please evaluate Mr. Maniam's teaching strategy by choosing the answer you think proper (POSTT 3-p.3)

D. Mr. Maniam should explain first the balloon will be attached to the wall if rubbed with certain materials, but not with other materials. Then he demonstrates it to the students, not the students asked to do those activities.

A. Mr. Maniam should explain first the balloon will be attached to the wall if rubbed with certain materials, but not with other materials. He then permits the students to do the experiments themselves.

B. So far the learning activities are good as long as Mr. Maniam can provide a framework about how students' findings are connected with learning goals, thus provide the correct conclusions.

C. In order to push the students to become independent researchers, Mr. Maniam should not provide explicit instructions. But he asks the students to do self-explorations with the balloon and provided materials and observe what will be going on.

The science teachers were expected to choose the open inquiry as the correct answer since the open inquiry actively engages students in activities and promotes their autonomies. In this

process, the teachers acted as the facilitators to help the students explore the science concepts. The percentages of all categories and the instrument's reliability were calculated using Rasch Analysis with Winstep.

RESULTS and DISCUSSION

As seen in Table 3, the science teachers considerably chose the open inquiry, especially on Q5 and Q8 (see Table 2). Meanwhile, the science teachers viewed Q4 as the guided inquiry for the most proper method.

Table 3. *Type of inquiry preferred by the science teachers*

Type of Inquiry	Number of responses on each item								
	1	2	3	4	5	6	7	8	9
Didactic direct	11	1	13	3	0	12	20	27	28
Active Direct	29	17	47	39	18	20	21	15	8
Guided Inquiry	24	46	8	54	44	41	39	11	43
Open Inquiry	41	41	37	9	43	32	25	52	26
Percentages of responses to open Inquiry	39.05	39.05	35.24	8.57	40.95	30.48	23.81	49.52	24.76

As observed from Table 3, a few science teachers selected didactic direct, while most of them chose either guided or open inquiry. Whereas they mostly marked didactic direct for Q9 (light and reflection) (n=28), they generally preferred active direct for Q3 (animal classification) (n=47). Meanwhile, they mostly selected the guided inquiry for Q4 (Microbes--n=54), the open inquiry for Q8 (static electricity--n=52).

For Q9 (light and reflection), most of the science teachers thought that the guided inquiry was better than the didactic direct. This means that some teachers tended to implement teacher-centered learning. Some of the science teachers did not give an opportunity for the students to explore their understanding of the 'light and reflection' topic through independent activities. In fact, because this topic has a lot of everyday life connections, an open inquiry is easily applied to this topic. The science teachers gave different responses to Q5 (characteristics of water). None of them chose the didactic direct. Indeed, majority of them selected the guided or open inquiry fostering students to explore and analyze the real-world phenomena. This implies that most of them may have used the inquiry-based learning on this topic. For Q3 (animal classification), active direct learning, in which students have little opportunity for verification stages, or teachers play dominant roles, was the most selected type.

The average percentages of didactic direct, active direct, guided inquiry, and open inquiry were 12.17, 22.65, 32.8 and 32.38 respectively. This means that 65.18% of the science teachers focused on the guided or open inquiry. In view of Wang and Jou (2016), the inquiry-based learning foster students' active participations in decision-making through scientific experiments, findings, and innovations. Hence, they develop their skills integrating and applying various aspects of science. Implementing the inquiry-based learning helps the teachers achieve the learning goals. The science teachers' various responses to each topic indicated that content knowledge or science topic drove the type of inquiry, and the open inquiry was not the only proper one for all science topics.

The lowest percentage in the didactic direct means that a few teachers used factual learning without focusing strongly on their students' autonomies. Phrased differently, the teacher-centered learning seems to have been less desirable.

The higher separation values mean the better instrument because of identifying respondent groups and item groups. Group separation can be determined with the formula of $H = [(4 \times \text{Separation}) + 1]/3$ (Sumintono & Widhiarso, 2014). As observed in Table 4, person separation value of $[(4 \times 1.39) + 1]/3 = 2.19$. If it is converted to 2, the value shows two respondent groups, i.e. direct teaching and inquiry learning groups. Item Separation value was $[(4 \times 2.52) + 1]/3 = 3.69$. If it is converted to 4, it reveals four answer groups: didactic direct, active direct, guided inquiry, and open inquiry. To sum up, these values address that the instrument is good, reliable, and can be used for further/future researches.

SUMMARY

This research showed that the science teachers' practical knowledge of the inquiry-based science teaching and learning leaned toward the high-level inquiry, i.e., guided inquiry and open inquiry. This finding indicated the readiness of the science teachers on the 21st century skills (e.g., communication, collaboration, critical thinking and creativity). The instrument may be used for an extended scale or a larger sample. To improve the science teachers' practical knowledge of the inquiry-based science teaching and learning, suitable seminars and trainings should be organized and implemented.

ACKNOWLEDGMENTS

This research was funded by the Grant for Post Graduate Research of Universitas Sebelas Maret.

REFERENCES

- Abd-el-khalick, F., Boujaoude, S., Duschl, R., Lederman, N. G., Mamlok-naaman, R., Hofstein, A., ... & Tuan, H. (2004). Inquiry in science education: International perspectives. *Culture and Comparative Studies*, 88, 397–419.
- Adofo, Stephen. (2017). *Teachers' Practical's About Inquiry in Science Education*. Philosophical Faculty University of Eastern Finland. Master Thesis in Science Education
- Alameddine, M. M., & Ahwal, H. W. (2016). Inquiry based teaching in literature classrooms. *Procedia - Social and Behavioral Sciences*, 232, 332–337.
- Avsec, S., & Kocijancic, S. (2014). Effectiveness of inquiry-based learning: How do middle school students learn to maximise the efficacy of a water turbine? *International Journal of Engineering Education*, 30, 1436–1449.
- Bhengu, T. T., & Mthembu, T. T. (2014). Effective leadership, school culture and school effectiveness: A case study of two “sister” schools in Umlazi Township. *Journal Social Science*, 38(1), 43–52.
- Buczynski, S., & Hansen, C. B. (2010). Impact of professional development on teacher practice: Uncovering connections. *Teaching and Teacher Education*, 26(3), 599.
- Castro, J. A. F. & Morales, M. P. E. (2017). “Yin” in a guided inquiry biology classroom – Exploring student challenges and difficulties. *Journal of Turkish Science Education*, 14(4), 48-65.
- Chinn, P. W. U. (2007). Decolonizing methodologies and indigenous knowledge: The role of culture, Place and personal experience in professional development. *Journal of Research in Science Teaching*, 44, 1247–1268.
- Cobern, W. W., Schuster, D., Adams, B., Skjold, B. A., & Mugaloglu, E. Z. Bentz, A., & Sparks, K. (2014). Pedagogy of science teaching tests: Formative assessments of

- science teaching orientations. *International Journal of Science Education*, 36, 2265-2288. DOI: 10.1080/09500693.2014.918672
- Comley, M. (2009). The inquiry-based science pedagogy debate. *Learning Landscapes*, 2, 155–166.
- Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching*, 44, 613–642.
- Drago, V., & Mih, V. (2015). Scientific literacy in school. *Procedia -Social and Behavioral Sciences*, 209, 167–172.
- Fernandez, C. (2014). Knowledge base for teaching and pedagogical content knowledge (PCK): Some useful models and implications for teachers' training. *Problems of Education in the 21st Century*, 60, 79-100.
- Feyzioglu, E. Y. (2015). Pre-service science teachers' pedagogical orientations of science inquiry continuum. *Bati Anadolu Eğitim Bilimleri Dergisi (BAED)*, 6(11), 1–36.
- Harris, C. J., & Rooks, D. L. (2010). Managing inquiry-based science: Challenges in enacting complex science instruction in elementary and middle school classrooms. *Journal of Science Teacher Education*, 21, 227–240.
- Hartings, M. R.; Fox, D. M.; Miller, A. E.; Muratore, K. E. A. (2015). Hybrid integrated laboratory and inquiry-based research experience: Replacing traditional laboratory instruction with a sustainable student-led research project. *J. Chem. Educ.*, 92, 1016–1023.
- Hong, C. E., & Lawrence, S. A. (2011). Action Research in teacher education: Classroom inquiry, reflection, and data-driven decision making. *Journal of Inquiry & Action in Education*, 4(2), 1–17.
- King, D., & Henderson, S. (2018). Context-based learning in the middle years: achieving resonance between the real-world field and environmental science concepts. *International Journal of Science Education*, 40, 1221-1238. <https://doi.org/10.1080/09500693.2018.1470352>
- Lederman, J. S. (2008). Teaching scientific inquiry: Exploration, directed, guided, and opened-ended levels. *Best Practices in Science Education*, 9–11.
- Ratinen, I., Viiri, J., Lehesvuori, S., & Kokkonen, T. (2015). Primary student-teachers' practical knowledge of inquiry-based science teaching and classroom communication of climate change. *International Journal of Environmental & Science Education*, 10, 649-670.
- Sierens, E., Vansteenkiste, M., Goossens, L., Soenens, B., & Dochy, F. (2009). The synergistic relationship of perceived autonomy support and structure in the prediction of self-regulated learning. *Br. J. Educ. Psychol*, 79(1), 57–68.
- Silva, T., & Galembeck, E. (2017). Developing and supporting students' autonomy to plan, perform, and interpret inquiry-based Biochemistry experiments. *J. Chem. Educ.*, 94(1), 52–60.
- Sumintono, B., & Widhiarso, W. (2014). *Aplikasi Model RASCH untuk Penelitian Ilmu-Ilmu Sosial (Rasch Model Application fo Social Sciences Research)*. Cimahi: Trim Komunikata Publishing House.
- Tafoya, E., Sunal, D., & Knecht, P. (1980). Assessing inquiry potential: A tool for curriculum decision makers. *School Science and Mathematics*, 80, 43–48.
- Ultay, N., & Calik, M. (2012). A thematic review of studies into the effectiveness of context-based chemistry curricula. *J. Sci Educ Technol*, 21, 686-701. DOI 10.1007/s10956-011-9357-5.
- Wang, J., & Jou, M. (2016). Qualitative investigation on the views of inquiry teaching based upon the cloud learning environment of high school physics teachers from Beijing, Taipei, and Chicago. *Computers in Human Behavior*, 60, 212–222.

- Zubaidah, S., Fuad, N. M., Mahanal, S., & Suarsini, E. (2017). Improving creative thinking skills of students through differentiated science inquiry integrated with mind map. *Journal of Turkish Science Education, 14*(4), 77-91.
- Zulfiani, Z. & Herlanti, Y. (2018). Scientific inquiry perception and ability of pre-service teachers. *Journal of Turkish Science Education, 15*(1), 128-140.

Applying an Experiential Learning Cycle with the Aid of Finite Element Analysis in Engineering Education

Indah WIDIASTUTI¹ , Cucuk W. BUDIYANTO²

¹ Dr., Mechanical Engineering Education, Universitas Sebelas Maret, Indonesia

² Ph.D, Informatics Education, Universitas Sebelas Maret, Indonesia

Received: 20.06.2018

Revised: 20.09.18

Accepted: 15.12.2018

The original language of article is English (v.15, n. Special Issue, December 2018, pp. 97-103, doi: 10.12973/tused.10261a)

ABSTRACT

To enhance student's understanding of basic engineering concepts, engineering education should include more active learning in its curricula. This article purposed to develop an active learning module for mechanical engineering students through a commercial finite element package. Kolb Learning Cycle was employed as the fundamental pedagogic of the module. This paper outlined how Kolb's theory of the experiential learning was used to improve a learning module for 'Heat Transfer' course in mechanical engineering education. This model, which covered three topics (steady state heat conduction, transient heat conduction and thermal stress), briefly summarized, and reviewed Kolb's stages of the experiential learning. A commercial finite element software was chosen to facilitate students' understanding of difficult mathematical concepts. Each stage of the learning module was highlighted. Recommendations were made for future evaluation and research.

Keywords: engineering education, experiential learning, Kolb's cycle, learning module

INTRODUCTION

Sustainable improvements in engineering education curricula significantly require to fulfill the demands of professional engineers in the current industry era. Increases in industry competitiveness and the massive use of new technology are the major factors forcing the transformation of engineering practice(s). Teaching engineering plays a crucial role in providing relevant knowledge and skills to meet any change in the industrial requirements. Basically, engineering education aims to equip students with specific knowledge and skills of science and engineering principles as well as general understanding of the product, process and system that constitute the society (Andersson & Andersson, 2010). Recent studies have revealed that the lecture-centred instruction is less suitable for educating future engineers and meeting the current instrual demands. There have been a wide gap in such industrial



requirements as a lack of communication and teamwork skills, inability to a broader societal perspective and good knowledge of fundamental engineering science (Li, Öchsner, & Hall, 2017).

Therefore, engineering education needs to create an active learning environment engaging students in learning process, and focus problems, design challenges and collaborative works on completing assignments and/or tasks (Pinder-Grover, 2013). Hence, such an approach not only enables students to retain their knowledge in long-term memory but also challenges to teach difficult engineering concepts/topics. For example; Clark, Thompson, and Mountcastle (2014) found that their students, who engaged in active-learning activities and spent more time to apply a mathematical definition on the real-life problems, successfully overcame their difficulties of a specific subject in a particular basic engineering course. Learning, which creates knowledge through the transformation of experience, is a continuous reconstruction of experience.

Learning from experience is the essence of experiential learning, which is a holistic model firstly introduced by Kolb (Kolb & Kolb, 2008). It consists of four elements: concrete experience, observation and reflection, the formation of abstract concepts and testing in a new situation. Abdulwahed and Nagy (2013) considered the Kolb's experiential learning framework as a suitable pedagogical model for engineering education. They also proposed a new approach for laboratory-based learning given the Kolb's theory. Jaksic (2010), who implemented the Kolb's cycle to teach Programmable Logic Control within a Computer Integrated Manufacturing course, reported that the students' design skills improved after implementing four quadrant learning activities. Several engineering courses have been developed in regard to the Kolb's cycle and Finite Element Analysis (FEA) commercial software (Brown et al., 2015; Brown et al., 2014; Watson, Brown, & Liu, 2015), such as machine design, mechanical vibration, structural analysis and biometrics. These courses have aimed not only to improve the students' understanding of the engineering concepts but also train them with the basic knowledge of the FEA theory. The Finite Element Analysis, which is a numerical method to find approximate solutions for complex engineering problems, usually represents the complicated mathematical form(s) of differential and integral equations (Widiastuti, 2014).

This article presents how to integrate experiential learning into engineering courses, which have no hands-on laboratory components. An experiential learning module for the students in *Heat Transfer* course was designed to incorporate a finite element analysis software. The module aimed to promote conceptual change for the students, which would serve as vocational teachers in engineering. This is unique to develop technical expertise of fundamental engineering concepts and encourage them to build their teaching/pedagogical identities.

METHODOLOGY

This article embraced the Kolb's constructivist model as a pedagogical basis to design the learning module for a *Heat Transfer* course. This course was part of the first-year curriculum of the Mechanical Engineering Education program at Sebelas Maret University. The module consisted of three sections, i.e, steady state heat transfer, transient heat transfer and thermal stress.

The experiential learning theory (ELT) model in this study depicted two related modes of grasping experience (Concrete Experience and Abstract Conceptualization) and two related models of transforming experience (Reflective Observation and Active Experimentation) (see Figure 1).

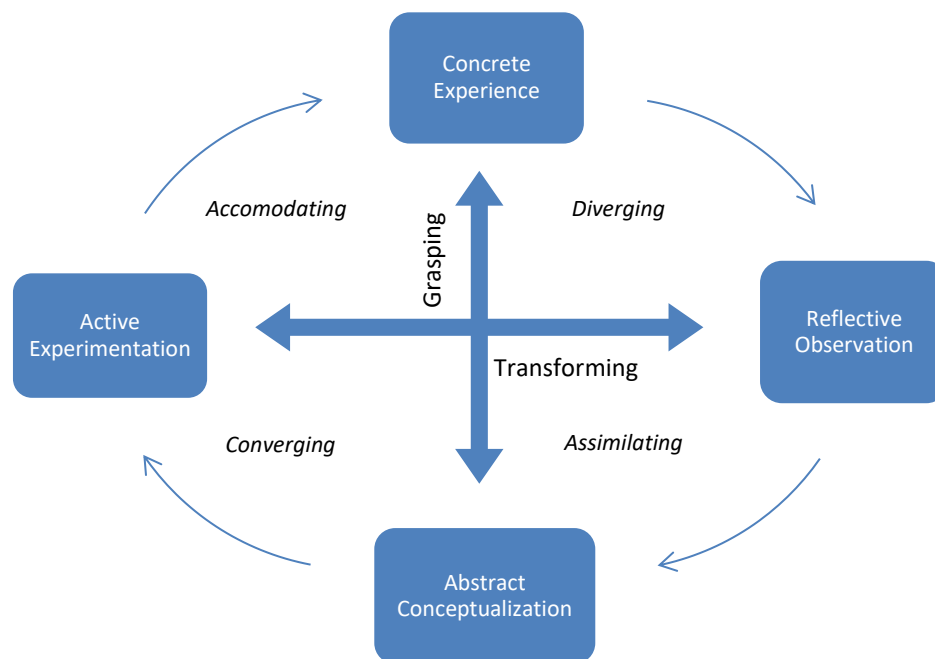


Figure 1. Experiential learning cycle (Kolb & Kolb, 2008)

As presented in Figure 1, the Kolb's cycle begins with a concrete experience whereas the learning process starts with doing something in an assigned task. In view of the Kolb's cycle, students cannot learn by simply watching or reading something, but they achieve to learn through active engagement.

The reflective observation, the second stage of the cycle, enables students to take time-out from "doing" and review previously grasped informations. At this stage, verbalization and discussion are required for teacher-student and student-student discourses.

The third stage engages students in making sense of the events, interpreting on what has happened, and understanding the relationship(s) between entities. This stage, called Abstract Conceptualisation, involves to compare *what has been done* with *what has already been known*.

The final stage, Active Experiment, affords students to transfer their generated knowledge into practicum. They are encouraged to plan what to do for a new understanding and to predict what happens in the next.

a) Implementation Of Elt For Heat Transfer Course

In *Heat Transfer* course, students are expected to improve their knowledge about heat conduction in solids for steady state and transient condition. This course, which has large enrollments with around 70 students, includes lectures and tutorials without a laboratory facility. The four-quadrant activities representing the ELT cycle were applied to three major topics with the aid of commercial finite element analysis software. By fully completing this cycle, the students were expected to have a stronger grasp of difficult concept(s) in *Heat Transfer*. Unlike previous works (Brown et al., 2014) introducing the FEA theory within the main topics, this module emphasized the use of the FEA software to illustrate the mathematical form and understanding of the basic engineering concepts. Pre-service vocational school teachers need strong mathematics and science knowledge to deliver the engineering concepts to their students (Asunda & Hill, 2008). The FEA theory, which includes intensive mathematics, requests students to possess more rigorous maths education (Watson et al., 2015).

As can be seen from Figure 1, the development of FEA-based learning module is pedagogically rooted in an experiential learning of the Kolb's cycle. Each section of the module presented the following sub-sections:

- Educational objective
- Problem description and objective analysis
- Mathematical equation
- General steps of the FE analysis
- Comparison of analytical and numerical analysis
- Summary and discussion

ANSYS® Workbench, a commercial FEA software, was linked with the module.

A module of heat transfer analysis using ANSYS Workbench was developed to be the supplement material for the heat transfer course. Section #1 focused on the steady state heat transfer, which aimed to assist students in visually verifying temperature distribution of an object under specified boundary conditions. During the introductory lecture of the Heat Transfer subject, the mathematical form of one-dimensional heat conduction was provided. In the first quadrant activities, group problem solving was chosen as a learning method to develop the FEA model of heat conduction in a plane wall. A problem was adopted from an example in Chapter 2 of a textbook of Heat Transfer (Cengel, 2003). This problem could easily be solved via hand calculations allowing a verification of the FEA solutions. The students were encouraged to precisely identify the boundary conditions of the problem following the tutorial provided in the module.

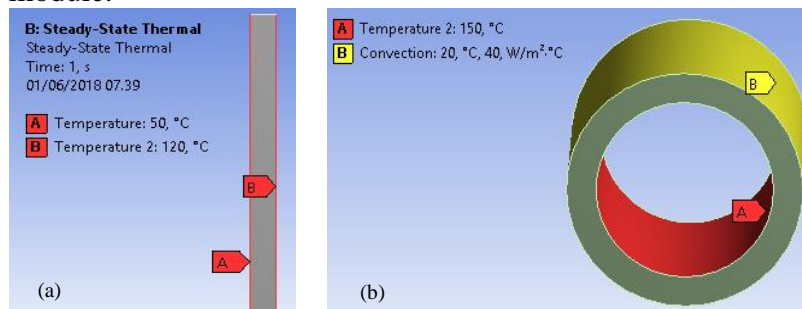


Figure 2. Heat conduction problem for (a) Section#1 and (b) Section#2

For the 'reflective observation' stage, the students were required to identify temperature distribution along the wall thickness from the ANSYS solution as well as compare the results with the analytical solution. In this stage, students were introduced to the use of the FEA as a numerical method to approximately obtain the solution in heat transfer. The teacher created a discussion environment about the effect of thermal conductivity on the rate of heat conduction under steady state. This led to the 'abstract conceptualisation' stage facilitating the students to understand the concepts of heat conductivity and heat flux. The problem of heat loss through a steam pipe was provided to engage the students in an active experiment to learn the heat conduction in a cylinder.

The learning outcome for Section#2 equipped the students with knowledge of thermal resistance relations and convection conditions at the boundaries. In the 'concrete experience' stage, the students presented their solutions of the problem provided in the previous section. After analysing the system's performance, the boundary in the outer surface of the cylinder was changed to a convection condition. The students had an observation on the variation of heat flux through the cylinder pipe as well as the effect of the convection on the heat flow. They were, then, be able to conceptualize the analysis of heat transfer in a medium consisting two or

more layers. In introducing the importance of insulator material and the effect of insulator radius on the rate of heat transfer within a cylinder shape, a case study of heat loss from steam pipe with insulator was provided for the active experiment in Section#2. The case study was adapted from Kreith, Manglik, and Bohn (2011).

The last section of the heat transfer learning module in this article handled the variation of temperature with time as well as the position in one-dimensional system. The one-dimensional transient heat conduction problem could be solved exactly for three basic geometries: plane wall, cylinder and sphere (Kreith et al., 2011). However, the solution involved infinites series that students found difficult. The general heat conduction equation in an infinite slab was described as

$$\frac{1}{\alpha} \frac{dT}{dt} = \frac{d^2T}{dx^2} \quad 0 \leq x \leq L(1)$$

In the ‘concrete experience’ stage, the students discussed the heat flux of the steam pipe with different insulator radius and types of material under steady state condition. Following the provided tutorial, they identified transient temperature profiles within the pipe during the ‘reflective observation’ stage. The students were expected to understand how to identify the difference(s) between steady state and transient modes of the heat transfer. The bimetallic strip problem derived from Boley and Weiner (1988) was selected for the project as the active experiment. This problem aimed to introduce the concept of thermal stress in advanced level of heat transfer subject. Table 1 summarizes all learning activities implemented during the heat transfer course with the aid of commercial FEA software.

Table 1. *Learning activities of each stage in the ELT’*

Stage	Section 1	Section 2	Section 3
Concrete experience	Enabled the students to developed a FEA model of heat conduction in plane wall	Afforded them to discuss the solution of heat transfer in a pipe and modify the boundary conditions with convection in outer surface of the pipe	Helped them brainstorm the heat flux in the pipe with different insulator parameters and follow the tutorial provided to develop the transient model of that problem
Reflective observation	Provided them to discuss the temperature distribution within the wall and make a prediction of the result for different thermal conductivity	Requested them to write a short report on the analysis of pipe problem with convection condition at the boundaries	Engaged them in making an observation on the temperature profile as a function of time and position
Abstract conceptualization	Enabled them to compare the numerical result(s) with analytical solution and lecture on the concept of thermal conductivity	Asked them to identify the differences between heat flux within a plane wall and a pipe and understand the concept of thermal resistance	Afforded them to discuss the elapsed time after the heat transfer was initiated and before the steady state conditions were reached

Active experimentation	Enabled them to develop and analyse heat loss in a steam pipe analytically and numerically	Required them to calculate thermal resistance in a steam pipe with different insulator diameters and materials	Helped them develop bimetallic strip problem via the FEA software by combining thermal and structural analysis
------------------------	--	--	--

CONCLUSIONS

This article implemented the Kolb's experiential learning cycle, as a teaching method, to the *Heat Transfer* in the pre-service vocational teacher education of mechanical engineering. It developed a series of learning activities in four quadrants representing the process of grasping and transforming the informations. The current study has not employed a formal assessment of this module; although the faculties' initial reactions were positive. Future studies should evaluate and assess the applicability of the Kolb's cycle. A long-term study implementing the experiential learning cycle will not only enhance student learning but also empower pre-service teachers' pedagogical skills.

ACKNOWLEDGMENTS

The author thanks to the Institute of Research and Community Service Universitas Sebelas Maret for the funding provided in performing this research.

REFERENCES

- Abdulwahed, M., & Nagy, Z. K. (2013). Applying Kolb's experiential learning cycle for laboratory education. *Journal of Engineering Education*, 98(3), 283-294.
- Andersson, N., & Andersson, P. H. (2010). *Teaching Professional Engineering Skills: Industry Participation in Realistic Role Play Simulation*. Paper presented at the The 6th International CDIO Conference, Montréal, Canada.
- Asunda, P. A., & Hill, R. B. (2008). Preparing Technology Teachers to Teach Engineering Design. *Journal of STEM Teacher Education*, 45(1), 26-52.
- Boley, B. A., & Weiner, J. H. (1988). *Theory of Thermal Stresses*. Mineola, New York: Dover Publications, Inc.
- Brown, A. O., Jensen, D. D., Schimpf, P. H., Crawford, R. H., Orabi, I. I., Watson, K. A., . . . Jackson, K. S. (2015). *Active Engineering Education Modules: A Summary of Recent Research Findings*. Paper presented at the 122nd ASEE Annual Conference & Exposition, Seattle, WA.
- Brown, A. O., Watson, K. A., Liu, J., Orabi, I. I., Rencis, J. J., Chen, C.-C., ... Jensen, D. D. (2014). *Assessment of Active Learning Modules: An Update in Research Findings*. Paper presented at the 121st ASEE Annual Conference & Exposition, Indianapolis, IN.
- Cengel, Y. A. (2003). *Heat Transfer: a Practical Approach* (2nd ed.): Mc-Graw Hill, Inc.
- Clark, J. W., Thompson, J. R., & Mountcastle, D. B. (2014). *Investigating Student Conceptual Difficulties in Thermodynamics Across Multiple Disciplines: The First Law and P-V Diagrams*. Paper presented at the 121st ASEE Annual Conference & Exposition, Indianapolis, IN.
- Jaksic, N. (2010). *Teaching PLCs Using the Kolb Learning Cycle*.
- Kolb, A. Y., & Kolb, D. A. (2008). Experiential Learning Theory: A Dynamic, Holistic Approach to Management Learning, Education and Development. In S. J. Armstrong &

- C. Fukami (Eds.), *Handbook of Management Learning, Education and Development*. London: Sage Publication.
- Kreith, F., Manglik, R. M., & Bohn, M. S. (2011). *Principles of Heat Transfer*. Stamford, CT, USA: Cengage Learning.
- Li, H., Öchsner, A., & Hall, W. (2017). Application of experiential learning to improve student engagement and experience in a mechanical engineering course. *European Journal of Engineering Education*, 1-11. doi:<http://dx.doi.org/10.1080/03043797.2017.1402864>
- Pinder-Grover, T. A. (2013). *Active Learning in Engineering: Perspectives from Graduate Student Instructors*. Paper presented at the 120th ASEE Annual Conference and Exposition.
- Watson, K. A., Brown, A. O., & Liu, J. (2015). *Finite Element Analysis Active Learning Modules Embedded Throughout A Curriculum: Implementation and Assessment of Results Based on Student GPA*. Paper presented at the 122nd ASEE Annual Conference & Exposition, Seattle, WA.
- Widiastuti, I. (2014). *Mechanical Performance of a PLA- based Biodegradable Plastic for Liquid Packaging Application*. (Doctor of Philosophy), Swinburne University of Technology, Melbourne, Australia.