

## ANALYSIS OF PROSPECTIVE PHYSICS TEACHERS' FEEDBACK ON ONLINE PEER-ASSESSMENT IMPLEMENTATION

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### ABSTRACT

This study aimed to analyse prospective physics teachers' feedback during the implementation of online peer-assessment in Teaching Physics in English course. Twenty prospective physics teachers participated in this study. They were familiar with the use of smart phone in their daily life. They tend to communicate using social media such as WhatsApp application. The students have practiced in using paper based peer-assessment in other courses, but they have not applied it in online method providing real time feedback and score. The implementation of online peer-assessment challenged the students to assess their peer objectively. The lecturers' feedback influence students' skills how to evaluate their peer performance. Several factors may influence the quality of students' online peer-assessment such as students' culture back ground, implementation of the online peer-assessment, and practicant's performance.

### ABSTRAK

Studi ini bertujuan untuk menganalisis balikan dari mahasiswa calon guru fisika dalam pelaksanaan *online peer-assessment* dalam matakuliah *Teaching Physics in English*. Dua puluh mahasiswa calon guru fisika berpartisipasi dalam kegiatan penelitian ini. Mereka sudah terbiasa menggunakan smartphone dalam aktivitas sehari-hari. Mereka cenderung menggunakan akun jejaring sosial seperti aplikasi *WhatsApp*. Mahasiswa calon guru fisika tersebut sudah pernah menerapkan kegiatan penilaian sejawat secara tradisional dengan menggunakan lembar pengamatan di matakuliah lain, akan tetapi mereka belum pernah menerapkan *online peer-assessment* yang menghasilkan skor penilaian dan balikan atau masukan yang secara langsung. Penerapan penilaian teman sejawat berbasis online ini memberikan tantangan bagi para mahasiswa untuk memberikan penilaian secara objektif. Balikan dari dosen mempengaruhi keterampilan mahasiswa dalam mengevaluasi teman sejawat mereka. Beberapa faktor yang mempengaruhi kualitas penilaian teman sejawat secara *online* dari mahasiswa calon guru fisika meliputi latar belakang sosial budaya mahasiswa, pelaksanaan kegiatan penilaian teman sejawat secara *online*, serta kualitas tampilan seorang practitioner di depan kelas.

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**Keywords:** analysis; feedback; pre-service physics teachers; online peer-assessment

### INTRODUCTION

Recently, prospective physics teacher have a global world challenge. This condition is supported by the rapid growth of Information and Communication Technology. The development of ICT with all the facilities offers a variety of facilities for humans in communicating

and activities. As part of the global community, prospective physics teacher should have adequate skills to face the future challenges. These challenges include the implementation of the ASEAN Economic Community (AEC). The implementation of the AEC gives consequences for the freedom of the incoming and outgoing flows of labor among ASEAN countries.

One of the provisions that must be had to face this challenge is the ability to teach physics in English. Teaching in English is not an easy

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matter for physics teacher candidates. Learning strategies, the selection of relevant topics, and the determination of the type of evaluation have an impact on the success of the students in teaching, of course it will be more impact if they have to prepare it in English.

The determination of effective evaluation type to measure the student's learning achievement is the main concern in this research. Applying effective and efficient assessment types is expected to enable optimal results in the implementation of learning. Theoretically, optimal results can be achieved if the students obtain an academic climate that supports and stimulates them to increase their competences. This academic climate is strived to be realized through the application of online peer-assessment.

Peer-assessment is part of formative assessment. This assessment is characterized by efforts of achieving the learning objectives and improving student achievement in Teaching Physics in English subject. The use of the assessment is also expected to improve the quality of learning and to enhance student participation in learning activities. Khusaini (2016) found that the use of online peer-assessment can increase the enthusiasm and participation of students in lectures. Student involvement in the peer-assessment activities is one of the new types of assessment implementations. This assessment allows students to increase their participation in learning activities as well as to increase their ability of self-evaluation (Dochy, Segers, & Sluijsmans, 1999; Valle, Andrade, Palma, & Hefferen, 2016).

The use of peer-assessment also has a positive impact in the development of student competence. Khusaini (2016) found that the ability of prospective physics teacher in the learning activities increased after receiving feedback from colleagues. This finding is supported by Topping (1999) who revealed that there is a positive impact of peer-assessment in improving students' learning achievement.

Online peer-assessment is part of the learning innovation that is supposed to be continuously improved. This innovation is characterized by the integrated use of ICT facilities in learning activities. The use of ICT tools allows positive impacts if applied appropriately. The use of ICT facilities can provide ease in giving feedback and improve the effectiveness of assessment activities to improve student achievement (Anderson, Healy, Kole, & Bourne, 2013; Klein & Kientz, 2013; Segedy; Kinnebrew; &

Biswas, 2013; Berry, 2009).

The use of online assessments as a form of integration of ICT facilities in peer-assessment has been investigated by Wen and Tsai (2008) who reported the positive impact of the use of the model in assessment activities in mathematics teachers. They both found that the quality of teacher appraisal skills during the use of ICT facilities is significantly increased. However, there is a negative side effect of the use ICT in the learning process. The teacher's attitudes and perceptions of online peer-assessment usage have shown a decreased impact. It need a further investigation to find the reasons since the assessment skill is a crucial skill to be mastered by the teachers.

Implementation of online peer-assessment has several challenges to be considered. The greatest challenge is how to provide objective assessments in a well-known Indonesian environment with high solidarity and familial values. Assessment and objective feedback from students to their friends are expected to improve student achievement. This objectivity also gained the attention of Liu and Charles (2006) suggesting that good peer assessment activities should continue to maintain quality feedback by preventing some factors that might reduce objectivity. They found a possible factor in reducing the objectivity of peer assessment such as gender.

The feedback given by lecturers in developing the students' ability should also be considered in implementing online peer-assessment. The feedback should always get attention both in terms of strategies and time management to be addressed. Various studies have shown that the teachers' feedback have a positif impact on students' learning motivation, students' understanding, as well as the quality of student behavior (Akalin & Sucuoglu, 2015; Seevers, et al., 2014; McLaren, 2012; Auld, et al., 2010; Vojdanoska, et al., 2010; Conroy, et al., & Vo, 2009; Brosvic & Epstein, 2007; Brosvic, et al., 2005). The findings indicate that it is still important to invite lecturers in addition to giving students' right to assess their peers. Therefore, the purpose of this study is to provide an overview of the role of online peer-assessment on prospective physics teachers' motivation. This study also aims to analyze the feedback and assessment provided by the students to each other; to provide important informations for researchers and practitioners who consider applying peer-assessment activities using popular ICT facilities such as WhatsApp

or other social media applications; as well as to provide an overview of the importance of feedback in improving the ability of students in assessing and in improving their learning achievement.

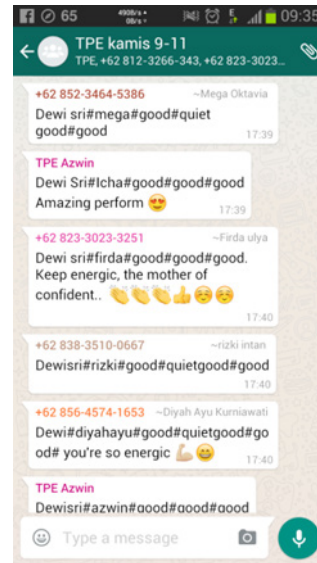
## METHOD

The study has used a qualitative approach. The data were collected from the recapitulation results of the communication flow that occurs during the online learning and online peer-assessment of Teaching Physics in English class. The recap of the communication result is then copied from the conversation via the WhatsApp application.

The number of respondents involved in this research activity is 20 prospective physics teacher. All the respondents involved are in the third year or in the sixth semester. They take this course as one of the preparations program before practicing the teaching experience in high school. All respondents have good English skills because they have followed the English course for physics. Some of the participants who take this course also take English for Physics course, which is a companion course to improve reading ability and explain some of the material of physics.

Respondents involved in the study consisted of two groups. The first group is the majority group (15 students) symbolized as participants (P) who enroll in the faculty officially. While the second group (5 students) are students who are motivated to improve their teaching skills in English with the permission of the lecturers without registering in the faculty symbolized as Non-Participant group (NP). Analysis of the influence of gender is done by giving the symbol F for female and the symbol M for male. Gender analysis is expected to describe the effect of gender on online peer-assessment.

Data collection using WhatsApp application is selected because it is widely used as a base program especially android smartphone. The WhatsApp application owned by the majority of students who have android based smartphones. They are accustomed to using this program to communicate. Assessment of students to their friend via WhatsApp application then implemented in the class group that has been previously established (Figure 1).



**Figure 1.** WhatsApp Group of Online Peer-Assessment in Teaching Physics in English (TPE) Class (Khusaini, 2016)

Assessments and feedback given by students to their peers have a certain format. The format is very simple and can be used all respondents quickly with the provision of assessment rubric (see Table 1). The respondents simply typed their score against a certain point and then added a reply to the performance of their friend (Figure 1). The format used in this peer assessment activity is to write the name of the presenter # name of appraiser # score for content criteria # score for communication clarity criteria # score for interaction with the audience # feedback or comments for the presentation of the presenter and suggestions for better performance. The format of this writing is quite simple and the respondent will be able to finish writing the format in just about a minute.

There are two basic information submitted before peer-assessment activity was done. First, students are given information of how to use the assessment rubric. Second, the students get information that the assessment does not affect the final value. Student participation in assessment activities is an exercise in evaluating peers in their class. Students are not required to do an assessment, but it is recommended to give an appraisal of their peers' performance. Assessment is done directly. Students have about five minutes to assess the performance of their friends. Any student who is present or who is absent still have opportunity to read the peer assessment results from performance inputs that is accompanied by feedback.

**Table 1.** Assessment rubric used in online peer assessment activities

Criteria	Less	Fair	Good
Content (30%)	Less Comprehensive or Having Misconception	Quite Comprehensive and No Misconception	Comprehensive and No Misconception
Communication Clarity (30%)	Unclear Pronunciation and Intonation Using Less Appropriate Word Choices	Quite good Pronunciation and intonation Using several appropriate word choices	Quite good Pronunciation and intonation Using several appropriate word choices
Interaction with the audience (40%)	Less keeping eye contact Less encouraging audience participation	Several keeping eye contact Several encouraging audience participation	Most keeping eye contact Most encouraging audience participation

Lecturers immediately read out the results of peer-assessment after the assessment entered the group. The lecturer gives feedback to the student's performance and also to the assessment or feedback given by the students in the peer-assessment. Data of comparative assessment given by between the lecturer and students' peer-assessment were analyzed. The analysis was focus on the tendency of students to assess their peers in peer teaching practice activities. Quantitative and qualitative approach were used in this research. Quantitative descriptive was used to describe the tendency of students in assessing each other. Quantitative data is presented in the form of frequency of peer-assessment aspects. In addition, qualitative analysis in the form of depiction of assessment is done by explaining all the facts in a deeper description.

The data collected in this research is a recording of all conversations and ratings occurring during peer-assessment activities by using the WhatsApp application that has transcript conversation facilities can be sent to email. The results of these conversations are analyzed and so the patterns can be taken. The conversation is finally grouped based on the time of peer assessment to know the pattern based on time.

## RESULTS AND DISCUSSION

The use of WhatsApp application in peer-assessment provides some convenience. Each respondent can directly respond both in the form of assessment and feedback on their peers' performance in the practice of peers teaching activity. The use of android application is effective and efficient due to the rapid flow of communication. Each student can find out the

scores of ratings and feedback as quickly as possible. Examples of feedbacks and groups contained in this peer assessment activity can be seen in Figure 1. Rapid rewinding time can have a direct effect to both the performance and the practitioner. Both parties can learn together and improve learning outcomes.

In this study students are grouped into four time groups. Time grouping is expected to provide an overview of the effect of study time with student assessment capability. The groups are sequentially grouped February 25, 2016, March 3, 2016, March 10, 2016, and the March 17, 2016 group. The first assessment group (February 25, 2016) can be seen in Table 2. In this assessment group, four students conducted teaching practice.

In this first week, the lecturer introduced how to use the rubric in the assessment activity. Assessment rubric already sent in previous day by email. Although newly introduced assessment rubrics, the number of students giving the same assessment or similar to the lecturers' assessment has increased even though the trend sometimes goes up sometimes down. In preliminary practice, the number of assessment that is in line with the assessment of lecturers is still two two students and eventually up to reach nine students.

The number of participating performances also experienced ups and downs starting at least 15 people and at most 17 people consisting of a mixture of P group and NP group. This increase can not be determined to match the expected amount because there is no obligation to provide an assessment, peer-assessment is not included in the final grade value, and not all students use their own smartphone. An increase in student ratings that is similar to lecturer assessment is possible because of the

**Table 2.** Recapitulation of the Implementation of the First Week

Practitioner	Input Values	Same Values	Feedback and Comments
A (F)	16 14 P 2 NP	2	15 students focus on one point, 1 student review all points 4 students less objective
B (M)	16 14 P 2 NP	6	4 students focus on 1 point, 2 students review only 2 points 4 female students less objektif 2 students less thorough to the content
C (F)	17 14 P 3 NP	9	Comments focus only on 1 point 1 student less objective 3 tudents wrong use rubric
D (M)	15 13P 2NP	4	Many constructive suggestions from students 5 students less objective

reversal of each peer assessment read and discussed.

In this first week also found the element subjectivity performance that gives better value to his/her close friend. The identification of the objectivity is done when the practitioner does not give a satisfactory performance. Errors in using the rubrics also occur in this week's assessment. This error is because it is still the first week and the lack of research students in using the rubric. The mistakes of both practitioner and performance concepts in basic physics concepts can also be identified through this peer-assessment. So this assessment is also useful for improving students' understanding of the concepts of physics. Concept error can be indicated from the performance' maximum value to the wrong concepts of practitioner performance.

Students' feedback on the performance of their peers has decreased in terms of the focus of the discussion in the points available in the rubric. In the first judgment, a student found a comment to all points in the rubric, while most focus on one point that is considered interesting. The pattern changed to two people commenting on two points of the rubric. Finally, all the student comments only focus one point that is considered important. The comments are more likely to motivate and compliment the performance of their friends as well as feedback for improvements to the next performance. This decrease is caused by not all students using their own smartphone. The second assessment group was conducted one week after the first group (March 3, 2016). Assessment analysis occurs in the second group can be seen in Table 3.

The phenomenon that occurs this week is slightly different. The second group experienced an increase in the same number of assessments as the lecturer's assessment. Students' comments are increasingly focused on points that are considered important. The number of participants involved in the assessment also increased. The least number of performances are 15 students, while the highest numbers are 18 students. Objectivity assessment of students is increasingly visible with marked suitability between performance with ratings and comments given by students with their peers' performance. The number of input comments is getting smaller as students tend to give judgment than comment. Students give comments only to give suggestions for better performance.

The improvement of the student's expertise in giving assessment to his colleagues is seen in this second week. This skill improvement is made possible by many things such as input and discussion by lecturers after the performance and discussion of the results of the assessment. The second factor is the learning process from the performance of practitioner in the first wave so that the second week practitioner performance improves and facilitates the peer assessment process. The challenge that is still visible and must be faced is still not fully all students use communication tools for assessment so that impact the assessment results.

The next assessment group is the third week group that was held on March 10, 2016. Implementation figures for this week can be seen in Table 4.

In this week, there is still no objectivity in the assessment. The cause of this inability

**Table 3.** Recapitulation of the Implementation of the Second Week

Practitioner	Input Values	Same Values	Feedback and Comments
E (F)	15	12	Focus on one point
	13 P		Give simple motivation by using emoticon.
	2 NP		Focus on interaction point
F (F)	17	10	Focus on one point
	14 P		More improvement remarks
	3 NP		
G (F)	17	17	9 feedback
	14 P		Short comments
	3 NP		Perfect performance
H (F)	18	11 7 mirip	9 feedback
	15 P		Short comments
	3NP		There is word "rather"
I (F)	18	18	8 feedback
	15 P		Short comments
	3 NP		
J (M)	18	18	12 feedback
	15 P		Comments in the form of motivation
	3 NP		

**Table 4.** Recapitulation of Third Week Implementation

Practitioner	Input Value	Same Value	Feedback and comments
K (M)	14	5	All students give comments
	12 P		Few of them less objective
	2 NP		
L (F)	14	14	13 students give comments
	12 P		
	2 NP		
M (F)	13	13	9 feedback
	13 P		Short comments
	0 NP		
N (F)	13	6	7 feedback
	13 P		Short comments
	0 NP		Few of them less objective
O (M)	11	11	7 feedback
	11 P		Short comments
	0 NP		

ty is the performance of practitioner who has not given the best performance will encourage students to act less objective in providing an assessment. Students tend to give better value to their close friends both male and female. This situation may be caused by Javanese cultural factors to emphasize brotherhood or feel uncomfortable if giving an assessment of their close friends. Gender factors are not very influential in the objectivity of this assessment. This objectivity factor can be generated by the

display of assessment after the assessment is completed followed by the discussion by the lecturer.

Comments given in reverse to the performance of practitioner increasingly conical with the need for input to improve the performance. Student performances are more likely to provide input to the practitioners who are deemed necessary to improve one aspect of the student practitioner.

This fourth week assessment group is

the last one. The number of practitioners was assessed by only one person. Notes during this assessment activity can be seen in Table 5. In the last assessment activity it can be said that all students have improved quite well. Students give the same assessment as many as six people and have similarities with the assessment of lecturer' assessment. Objective factors in the assessment activities are well ordered. All of the student assessments commented on the students' performance. These comments tend to motivate and provide input for performance improvement.

**Table 5.** Recapitulation of Fourth Week Implementation (March 17, 2016)

Practitioner	Input Value	Same Value	Feedback and Comments
P (p)	12 12 P 0 NP	12	12 Comments Motivate feedback and suggestions for improvement

Improving the assessment of the student performances is caused by several things. First, students are more observant in the assessment activities. Students have shown a critical way of thinking to assess student practitioners. Second, the feedback given by the lecturer to each student input can be used as an example for the student appraiser in the next week's assessment activity. Giving feedback from this appraiser also has a positive impact on the practitioner. The practitioners can know the shortcomings and advantages.

Based on the analysis of peer-assessment activities, it can be concluded that there is an increase in the ability of peer-assessment by respondents. Feedback from the lecturer has a positive impact on student appraisers and practitioners. This condition is in accordance with the findings of Akalin and Sucuoglu (2015) which found a positive influence on improving the characteristics and ability of students in learning. Several studies also reinforce the importance of appropriate feedback to improve learning achievement and change the behavior of prospective students (Auld et al., 2010) and teachers who attend training (Duchaine, et al., 2011). Similar findings regarding repatriation according to student shortcomings were also found by Nuryantini, et al. (2015). They were indicating an improvement in the learner's ability after receiving feedback in classroom action research using authentic assessment.

Feedback technique should also be considered to give a positive impact. Seevers, et al. (2014) found the need to give positive feedback in public, and to give negative ones personally to positively affect students. The importance of effective feedback was also highlighted by Conroy, et al. (2009) which emphasizes the importance of appropriate feedback to foster student potential. Vojdanoska, et al. (2010) also reinforces the notion of the importance of giving feedback to instill a better skill to learners.

This study found that direct feedback can have a positive effect in improving students' ability to assess and practice teaching. This finding is in contrast to Brosvic, et al. (2005) who found that direct feedback only provided repetition and acquisition skills alone. Brosvic and Epstein (2007), however, found that direct feedback has an excellent impact on a valuation process, especially a matter of multiple choices. The time choice as a learnable moment is a crucial marker of the importance of effective timing of feedback. Feedback development should be done to improve the role of assessment in support of student learning activities. The addition of audio visual means and responses to the feedback given by peers should be done in further research. McLaren (2012) found that more varied feedbacks with audio visual means and student attitudes toward feedback allow for better learning. This process of feedback and media interaction makes it possible to streamline the role of feedback in peer-assessment activities.

Cultural factors of student origin should also be considered. Solidarity culture and mutual respect for friends should be considered as well. This factor may affect the subjectivity of student as an assessor. The factor is then influenced by less than the maximum performance of a practitioner. A practitioner who performs teaching skills in English that are not so maximized can get the maximum value from a close friend. The influence of this culture is much greater than the gender factor of the performance and practitioner.

Concept errors in Physics can also be checked during online peer-assessment activities. The lecturer is easier to detect the mistake of the practitioner concept during the teaching practice. The mistake of the assessor' concept can be checked from their score and feedback. It became the perfect moment to provide improved student concepts through lecturer feedback (Akalin & Sucuoglu, 2015; Conroy et al.,

2009; Brosvic & Epstein, 2007).

## CONCLUSION

Online peer-assessment activities shows a positif impact in the Teaching Physics in English learning. The prospective physics teacher get more opportunity to learn how to conduct assessment in physics learning. Their capabilities in assessments activities were increase significantly by considering the lecturer' assessment in the learning process. Factors that influence the prospectice students' performance in peer-assessment activies include: Javanis cultural background, online process which enable the practitioner know who is her/his assessors, as well as the quality of the practitioner in front of class.

## REFERENCES

- Akalin, S., & Sucuoglu, B. (2015). Effects of Classroom Management Intervention Based on Teacher Training and Performance Feedback on Outcomes of Teacher-Student Dyads in Inclusive Classrooms. *Educational Sciences: Theory and Practice*, 15(3), 739-758.
- Anderson, L. S., Healy, A. F., Kole, J. A., & Bourne, L. E. (2013). The clicker technique: Cultivating efficient teaching and successful learning. *Applied Cognitive Psychology*, 27(2), 222-234.
- Auld, R. G., Belfiore, P. J., & Scheeler, M. C. (2010). Increasing pre-service teachers' use of differential reinforcement: Effects of performance feedback on consequences for student behavior. *Journal of Behavioral Education*, 19(2), 169-183.
- Berry, J. (2009). Technology support in nursing education: Clickers in the classroom. *Nursing Education Perspectives*, 30(5), 295-298.
- Brosvic, G. M., & Epstein, M. L. (2007). Enhancing learning in the introductory course. *The Psychological Record*, 57(3), 391.
- Brosvic, G. M., Epstein, M. L., Cook, M. J., & Dihoff, R. E. (2005). Efficacy of error for the correction of initially incorrect assumptions and of feedback for the affirmation of correct responding: Learning in the classroom. *The Psychological Record*, 55(3), 401.
- Conroy, M. A., Sutherland, K. S., Snyder, A., Al-Hendawi, M., & Vo, A. (2009). Creating a Positive Classroom Atmosphere: Teachers' Use of Effective Praise and Feedback. *Beyond Behavior*, 18(2), 18-26.
- Dochy, F., Segers, M., Sluijsmans, D. (1999) The use of Self-, peer-, and Co-Assessment in Higher Education: a Review. *Studies in Higher Education*, 24(3), 331-350.
- Duchaine, E. L., Jolivet, K., & Fredrick, L. D. (2011). The effect of teacher coaching with performance feedback on behavior-specific praise in inclusion classrooms. *Education and Treatment of Children*, 34(2), 209-227.
- Khusaini. (2016). Online Peer-Assessment in Teaching Physics in English class for improving pre-service physics teachers learning. Makalah disajikan dalam 3rd International Conference on Research, Implementation and Education of Education of Mathematics and Science, FMIPA Universitas Negeri Yogyakarta, 16-17 Mei.
- Klein, K., & Kientz, M. (2013). A model for successful use of student response systems. *Nursing education perspectives*. 34(5), 334-338.
- Liu, Ngar-Fun & Carless, David. (2006). Peer feedback: the learning element of peer assessment. *Teaching in Higher education*, 11(3), 279-290.
- McLaren, S. V. (2012). Assessment is for learning: supporting feedback. *International Journal of Technology and Design Education*, 22(2), 227-245.
- Nuryantini, A. Y., Setiadi, T., Kurniawan, K., & Farida, I. (2015). The Application Of Authentic Assessment With Feedback To Improve The Competence Of Mts 2 Bandung Students In Constructing A Scientific Report Of Motion Material In Science Learning. *Jurnal Pendidikan Fisika Indonesia*, 11(2), 108-116.
- Seevers, M. T., Rowe, W. J., & Skinner, S. J. (2014). Praise in public, criticize in private? An assessment of performance feedback transparency in a classroom setting. *Marketing Education Review*, 24(2), 85-100.
- Segedy, J. R., Kinnebrew, J. S., & Biswas, G. (2013). The effect of contextualized conversational feedback in a complex open-ended learning environment. *Educational Technology Research and Development*, 61(1), 71-89.
- Topping, Keith. (1999). Peer Assessment between students in Colleges and Universities. *Review of Educational research*, 68 (3), 249-276.
- Valle, C., Andrade, H., Palma, M., & Hefferen, J. (2016). Applications of Peer Assessment and Self-Assessment in Music. *Music Educators Journal*, 102(4), 41-49.
- Vojdanoska, M., Cranney, J., & Newell, B. R. (2010). The testing effect: The role of feedback and collaboration in a tertiary classroom setting. *Applied Cognitive Psychology*, 24(8), 1183-1195.
- Wen, M. L., & Tsai, C. C. (2008). Online peer assessment in an inservice science and mathematics teacher education course. *Teaching in Higher Education*, 13(1), 55-67.



# TSUNAMI-MAGNETIC SIGNALS AND MAGNETIC ANOMALY GENERATED BY TSUNAMI WAVE PROPAGATION AT OPEN SEAS

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## ABSTRACT

This research examines the generation of tsunami-induced magnetic signals, where local magnetic anomaly were measured as variations in the vertical  $b_z$  and horizontal  $b_H$  components of the secondary field. The maximum amplitudes of  $b_z$  and  $b_H$  were analytically estimated and compared to magnetogram provided by INTERMAGNET and BCMT for the 2010 Chilean, the 2011 Tohoku, the 2010 Mentawai and the 2004 Aceh tsunamis. For the first two cases, frozen-flux theory was used to estimate  $b_z$  and  $b_H$  where the phase lag between  $b_z$  and  $b_H$  was  $\pi/2$ , relevant to time interval of  $T/4$  between the two signals. For the Mentawai case, oceanic diffusion was unignored and  $b_z$  significantly deviated from that calculated using the theory. However, the data from Mentawai where  $b_z \leq 2$  nT were in good agreement with  $b_z$  generated by large tsunamis occurring in regions near the equator and with magnetogram from the Aceh event.

## ABSTRAK

Penelitian ini mempelajari pembangkitan sinyal magnetik akibat perambatan tsunami. Gangguan fisis pada permukaan laut menyebabkan anomali magnetik yang terukur sebagai variasi komponen vertikal  $b_z$  dan horisontal  $b_H$  medan sekunder. Amplitudo maksimum  $b_z$  dan  $b_H$  dihitung secara analitik dan dibandingkan dengan magnetogram dari INTERMAGNET dan BCMT untuk tsunami Chili 2010, Tohoku 2011, Mentawai 2010 dan Aceh 2004. Untuk kasus Chili 2010 dan Tohoku 2011, pendekatan *frozen-flux* secara efektif digunakan untuk estimasi  $b_z$  dan  $b_H$  di mana beda fase antara  $b_z$  dan  $b_H$  diprediksi  $\pi/2$  yang setara dengan selang waktu  $T/4$  antara kedua sinyal magnetik tersebut. Untuk kasus Mentawai 2010, difusi air laut tidak bisa diabaikan sehingga pendekatan *frozen-flux* menyimpang signifikan. Namun demikian, data kasus Mentawai 2010 di mana diperoleh  $b_z \leq 2$  nT sesuai dengan estimasi analitik amplitudo maksimum  $b_z$  yang dibangkitkan oleh tsunami besar di wilayah ekuator yang ternyata juga sesuai dengan data magnetogram kasus Aceh 2004.

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**Keywords:** magnetic anomaly; secondary field; frozen-flux theory; magnetogram

## INTRODUCTION

This study examines tsunami-generated magnetic signals in the context of ocean dynamo effects, where the movement of electrically conducting seawater across the ambient geomagnetic field induces secondary magnetic fields (Tyler, 2005). Such perturbations on the sea surface produce local anomaly with respect

to the Earth's magnetic field, which is measured as the vertical and horizontal components of the secondary field. Although the maximum amplitude of the local anomaly is relatively small compared to the main field, it can still be detected by sensitive instrument (Manoj, Maus, & Chulliat, 2011; Ichihara, Hamano, Baba, & Kasaya, 2013; Minami & Toh, 2013; Sugioka *et al.*, 2014). The maximum amplitude is possibly determined by either analytical estimate or visual inspection upon magnetogram obtained from a global magnetic network of International

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Real-time Magnetic Observatory Network (IN-TERMAGNET) as reported by Klausner, Domingues, Mendes, & Papa (2011) and Bureau Central de Magnetisme Terrestre (BCMT) as used by Wang & Liu (2013). Similarities found in the vertical and horizontal components of the tsunami-magnetic signals between analytical estimate and visual inspection on magnetogram provided by the two global institutions are tested for several cases of large tsunamis.

Recent studies (e.g., Tatehata, Ichihara, & Hamano, 2015) relevant to the generation of magnetic signals and local magnetic anomaly due to tsunami wave propagation have utilized numerical simulation to better understand mechanisms of production and variation of the secondary field. Other studies (e.g. Minami, Toh, & Tyler, 2015) have also been based on computational work examining effects of sea-depth parameter on tsunami wave propagation characteristic at open seas and determine whether advection or diffusion is the dominant physical process in a particular area in the ocean. As evaluated by Klausner, Kherani, & Muella (2016), a combined work of both computational techniques and field observations for determining the vertical component  $b_z$  of tsunami-induced signals revealed the same results obtained for separate considerations of near- and far-field distances from a tsunami source.

Minami *et al.* (2015) discussed the roles of ocean depth  $h$  in terms of a functional relationship between the external parameter (ocean diffusivity  $\kappa$ ) and internal parameters (tsunami phase speed  $c$  and the complex speed of ocean waves  $c_s$ ). By adopting ideas of Tyler (2005) and using research findings of Minami *et al.* (2015), we examine the dependence of local magnetic disturbance  $b_z/F_z$  where  $F_z$  denotes the vertical component of the main, Earth's magnetic field upon two dimensionless physical parameters, namely:  $h/L$  where  $L = 2.53$  km is the characteristic lengthscale (Minami *et al.*, 2015) and  $c/c_s$  where  $c_s$  is defined as  $c_s = c + ic_d$  with  $c_d$  is the rate of oceanic diffusion process (Tyler, 2001).

In this study, four large tsunami occurrences caused by earthquakes with magnitudes of  $M_w \geq 7.8$  are separately examined and discussed, namely: the 2010 Chilean and the 2011 Tohoku events, where advection dominates over diffusion, and the 2010 Mentawai and the 2004 Aceh tsunamis, where oceanic diffusion cannot be ignored. Discussion for all cases focuses on the roles of important parameters  $h/L$  and  $c/c_s$  for use in determining a proper

formula to accurately estimate the vertical and horizontal signals of the tsunami-induced field.

As reported by Satriano, Wu, Zollo, & Kanamori (2011) and Satake (2014) in terms of concepts and methods of earth-related disaster risk reduction (for example, earthquakes and tsunamis), monitoring of tsunami-generated magnetic signals and the corresponding magnetic anomaly in the present study could thus be an alternative method for the development of a tsunami early warning system. Therefore, this research is expected to give shed light on researchers working on a similar subject and may then complete the existing method of seismic monitoring for tsunami early warning, such as the Indonesian Tsunami Early Warning System (Ina-TEWS) organized by the Indonesian Agency for Geophysics, Climatology, and Meteorology (BMKG). In addition, mechanisms of the generation of tsunami-magnetic signals and magnetic anomaly would be useful for enriched physics teaching materials in schools and universities. This is made possible because basic physics principles of such a phenomenon are derived from a set of Maxwell's equations, including the concept of electromagnetic induction widely known as Faraday and Biot-Savart laws, and Ohm's law for a moving conductor across magnetic lines of force.

## METHOD

The governing equation required for examining fundamental mechanisms of the generation of tsunami-magnetic signals and magnetic anomaly in the oceans is as follows,

$$\partial_t b_z = -\nabla_H \cdot (F_z \mathbf{u}_H) + \kappa \nabla^2 b_z \quad (1)$$

which is commonly known as the electromagnetic induction equation (Tyler, 2005; Ichihara *et al.*, 2013; Sugioka *et al.*, 2014; Minami *et al.*, 2015). The left-hand side of equation (1) describes time evolution of the vertical component  $b_z$  of the secondary field. The first term of the right-hand side denotes secondary field production by fluid flow of electrically conducting seawater (horizontal advection) while the second term represents contra-production of the secondary field by ocean local circulation (vertical diffusion).

Tyler (2005) evaluated the relative importance of each term on the right-hand side in equation (1) and reported that the ratio of local magnetic disturbance relative to the main geomagnetic field  $b_z/F_z$  is proportional to the ratio of local perturbation in the sea surface elevation relative to the ocean depth  $\eta/h$ . In this con-

text,  $\eta$  is the maximum vertical displacement of the sea surface owing to tsunami propagation. This idea was adopted and then further developed by Ichihara *et al.* (2013), Sugioka *et al.* (2014) and Minami *et al.* (2015) to derive equations necessary for estimating both the vertical  $b_z$  and horizontal  $b_H$  components of the tsunami-induced field. When oceanic diffusion can be neglected or in other words, horizontal advection dominates over vertical diffusion ( $c/c_s \approx 1$ ), it is true that

$$b_z/F_z = \eta/h \quad (2)$$

which is well known as *frozen-flux* approximation, commonly used for analytical estimate of  $b_z$  given that the other three variables in equation (2) are known. The horizontal component  $b_H$  of the induced field is then calculated from

$$b_H = i b_z \quad (3)$$

which clearly indicates a phase difference between vertical and horizontal tsunami-magnetic signals.

Minami *et al.* (2015) found diffusion effects unignorable, particularly in parts of the ocean where  $h/L < 2.0$  such that equation (2) becomes

$$b_z/F_z = c/c_s \times \eta/h \quad (4)$$

The rate  $c_d$  of diffusion process at seas is defined as  $c_d = 2\kappa/h$  and the phase speed  $c$  of a tsunami wave is written as  $c = (gh)^{1/2}$  where  $g$  is the gravitational acceleration.

Equation (4) shows that the ratio of  $b_z/F_z$  depends upon the ocean depth  $h$  and is implicitly determined by two physical processes in the oceans, namely advection process represented by  $c$  and diffusion process denoted by  $c_d$  in terms of  $c/c_s$ . This parameter plays a role in determining which process is dominant over the other in the oceans. When  $c/c_s \approx 1$  is satisfied, *frozen-flux* approximation holds and when  $c/c_s < 1$ , *frozen-flux* approximation gives estimate of  $b_z$  that significantly deviates from the expected value.

In line with zonal divisions at which a particular process is dominant in the oceans, Minami *et al.* (2015) proposed that oceanic zones are divided into regimes based on the ratio of  $h/L$  where  $L$  is defined as  $L = (2\kappa/g^{1/2})^{2/3} = 2.53$  km. Considering this, three dynamic regimes are as follows: (1)  $0 \leq h/L \leq 0.5$  where diffusion is adequately strong; (2)  $0.5 \leq h/L \leq 2.0$  where diffusion and advection are in balance; and (3)  $h/L \geq 2.0$  where advection dominates over diffusion.

The methods including procedures and steps used in the current study involved data

inputs, estimation processes, and outputs. All numerical values for the geomagnetic field  $F_z$  were obtained for free from [www.ngdc.noaa.gov/IAGA/vmod/](http://www.ngdc.noaa.gov/IAGA/vmod/) (International Association of Geomagnetism and Aeronomy [IAGA], 2016) in the form of geomagnetic coefficients issued for the 12th Generation of International Geomagnetic Reference Field (IGRF), numerical data for the global bathymetry of sea depth  $h$  were also obtained for free at [www.ngdc.noaa.gov/mgg/global/relief/ETOPO1/](http://www.ngdc.noaa.gov/mgg/global/relief/ETOPO1/) (National Geophysical Data Center [NGDC], 2016), numerical data for maximum amplitudes of the sea surface elevation  $\eta$  for four large tsunamis, namely: the 2010 Chilean, the 2011 Tohoku, the 2010 Mentawai, and the 2004 Aceh were also freely available at [www.ngdc.noaa.gov](http://www.ngdc.noaa.gov) (National Oceanic and Atmospheric Administration [NOAA], 2016). For comparison, careful visual inspection upon magnetogram freely accessible at [www.intermagnet.org](http://www.intermagnet.org) (INTERMAGNET, 2016) and [www.bcmt.fr](http://www.bcmt.fr) (BCMT, 2016) was then performed.

Analytical estimates of  $b_z$  and  $b_H$  have used equations (2) and (3) for tsunamis triggered by large earthquakes, that is, the 2010 Chilean and the 2011 Tohoku events as the two events satisfy criteria for *frozen-flux* approximation. For the 2010 Mentawai tsunami, a number of field data were consistent with advection case requirement ( $c/c_s \approx 1$  and  $h/L \geq 2.0$ ) where *frozen-flux* approximation remained effective, and other data records were partially at a regime where oceanic diffusion effects started to influence (*intermediate regime*) and the rest were classified into the dominant diffusion regime. Therefore, estimate of  $b_z$  for the Mentawai tsunami used equation (4) but values of  $b_H$  for the same case were still estimated using equation (3). The 2004 Aceh tsunami is here discussed in comparison with that of the Mentawai. Outputs of all cases considered in this study are values of  $b_z$  and  $b_H$  obtained from analytical estimates for cases either with *frozen-flux* or with no *frozen-flux* approximation and visual estimates through inspection on either magnetogram provided by INTERMAGNET and BCMT or relevant graphs of magnetic variations recorded by magnetic instrument deployed at the sea floor, such as Ocean Bottom Electromagnetometer (OBEM).

## RESULTS AND DISCUSSIONS

Two large tsunamis firstly discussed are the Chilean event that occurred on 27 February

2010 with the epicenter is located at 36.1° S and 72.6° W, tsunami origin time (OT) at 06:44 Universal Time Coordinates (UTC), and magnitude of  $M_W$  8.8 and the other that occurred in Tohoku on 11 March 2011 with the epicenter at 38.3° N and 142.4° E, tsunami OT at 05:51 UTC, and magnitude of  $M_W$  8.9. Table 1 contains complete data listing names of magnetic station with their corresponding geographical positions, numerical values of  $F_z$ ,  $\eta$  and  $h$  obtained from relevant sites previously stated, and the vertical component  $b_z$  calculated using equation (2). IPM, PPT, and KAK are names of magnetic station while B14 (one of OBEM as used by Ichihara *et al.*, 2013) is sensitive instrument deployed at the sea floor having the same function as magnetic station to monitor electromagnetic signals induced by tsunami waves.

Values for  $b_z$  in Table 1 are tested by recalculating them with respect to the effects of oceanic diffusion (see corresponding values in Table 2). Indeed,  $b_z$  is recalculated using equation (4) in which some physical quantities needed are as follows:  $\kappa = (\mu\sigma)^{-1}$  with  $\mu \approx \mu_0 = 4\pi \times 10^{-7} \text{ WbA}^{-1}\text{m}^{-1}$  (ocean magnetic permeability),  $\sigma \approx 4 \text{ Sm}^{-1}$  (conductivity of seawater) and the complex speed of ocean waves  $c_s$  calculated from  $c_s = (c^2 + c_d^2)^{1/2}$  where  $c$  and  $c_d$  are previously defined.

Table 2 provides recalculated values for  $b_z$  using equation (4), where the results differ by  $\leq 7\%$  from those calculated using equation (2). This discrepancy is considered insignificant hence *frozen-flux* approximation remains valid. This argument is supported by values listed in

columns 4 and 8 in Table 2, where  $h/L \geq 2.0$  and  $c/c_s \approx 1$  are found in all monitoring stations for the two events. With respect to small perturbations of  $b_z$  from its maximum amplitude, *frozen-flux* theory is proved to be reliable and effective for use to estimate  $b_z$  accurately enough, in particular when diffusion effects are ignorable.

As previously written, estimates of  $b_z$  using both equations (2) and (4) are compared with records of magnetogram provided by the global network of INTERMAGNET and BCMT. Graphical magnetogram indicates that for the 2010 Chilean event there is a periodic signal of magnetic variations observed and measured by instrument at IPM seen in Figure 1 for magnetogram from INTERMAGNET and in Figure 2 for magnetogram from BCMT.

Figure 1 clearly shows effects of local disturbances on the sea surface due to earthquake with large magnitude that occurred off the coast of Chili, where the disturbances generated a giant tsunami wave propagating across the Pacific and then arriving at IPM 3500 km away from the epicenter. In turn, magnetic perturbations due to tsunami wave propagation were well recorded as the periodic signal  $b_z$  of the secondary field (denoted by three red-circles in the Z component of INTERMAGNET magnetogram). The periodic signal is obviously observed to occur around 11:45 UTC and provides a convincing clue for the magnetic anomaly with the mean value of the amplitude is best estimated at about 0.47 nT.

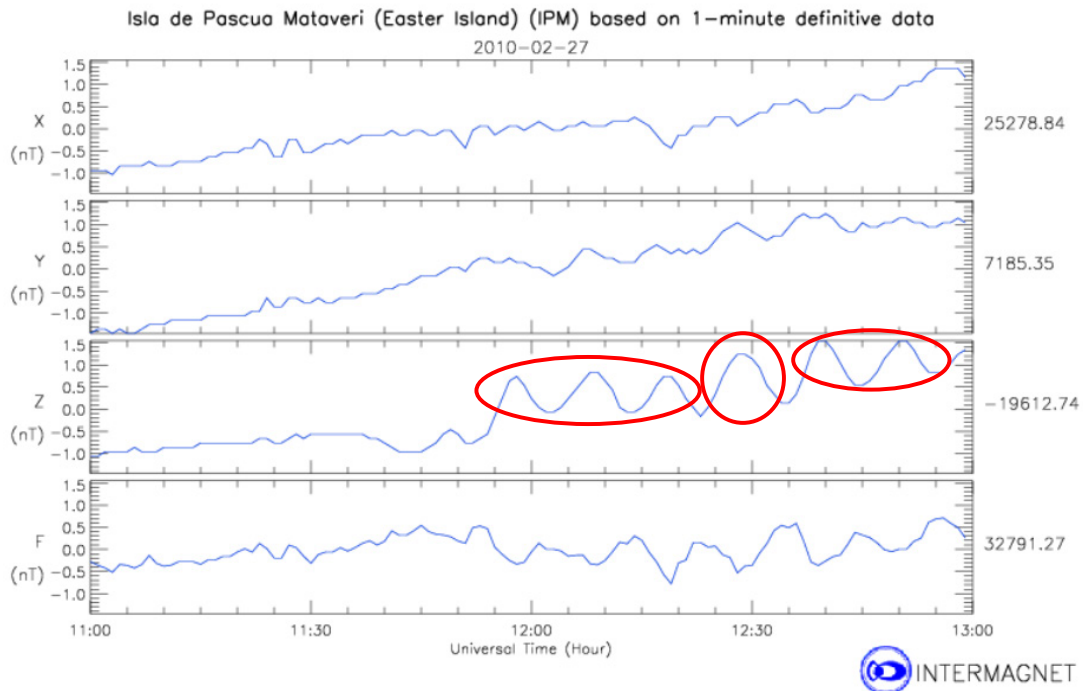
For comparison, Figure 2 provides magnetogram from BCMT for the same event. The periodic tsunami-magnetic signal was also re-

**Table 1.** Data for the 2010 Chilean and the 2011 Tohoku events with  $b_z$  is calculated using equation (2).

Tsunami Event	Magnetic Station	Latitude Position	Longitude Position	$F_z$ (nT)	$\eta$ (m)	$h$ (m)	$b_z$ (nT)
2010 Chilean	IPM	27.17° S	109.41° W	19019.6	0.15	6933	0.41
	PPT	17.57° S	149.57° W	18886.0	0.12	5085	0.45
2011 Tohoku	B14	39.03° N	144.48° E	37271.6	2.35	5830	15.02
	KAK	36.23° N	140.18° E	35619.2	4.50	10272	15.60

**Table 2.** Data for the 2010 Chilean and the 2011 Tohoku events with  $b_z$  is calculated using equation (4).

Tsunami Event	Magnetic Station	$h$ (m)	$h/L$	$c$ (ms <sup>-1</sup> )	$c_d$ (ms <sup>-1</sup> )	$c_s$ (ms <sup>-1</sup> )	$c/c_s$	$b_z$ (nT)
2010 Chilean	IPM	6933	2.7	260.7	57.4	266.9	0.98	0.40
	PPT	5085	2.0	223.2	78.3	236.6	0.94	0.42
2011 Tohoku	B14	5830	2.3	239.0	68.3	248.6	0.96	14.45
	KAK	10272	4.1	317.3	38.8	319.6	0.99	15.49



**Figure 1.** Magnetogram from INTERMAGNET for the 2010 Chilean tsunami occurrence recorded at IPM (3500 km away from the epicenter) after 5-hours travelling from the epicenter towards IPM.

corded at IPM run by BCMT, where the magnetic anomaly started to observe at 11:45 UTC with the mean amplitude of about 0.48 nT. This value is considered insignificant difference from that given by INTERMAGNET.

Data for magnetogram from both INTERMAGNET and BCMT are also in good agreement with variations in hydrostatic pressure at the ocean bottom measured by OBEM close to IPM location, where maximum hydrostatic pressure variation is estimated to be equal to  $b_z \approx 0.50$  nT (Sugioka *et al.*, 2014). The amplitude of the signal is consistent with *peak-to-peak* variation of  $b_z$  at about 1.0 nT suggested by Manoj *et al.* (2011) for the same tsunami. A slight difference in the results between analytical estimates and visual inspection using magnetogram is attributed to inaccuracy of ocean depth measurements of  $h$  obtained from a world map of ocean topography from global bathymetry data.

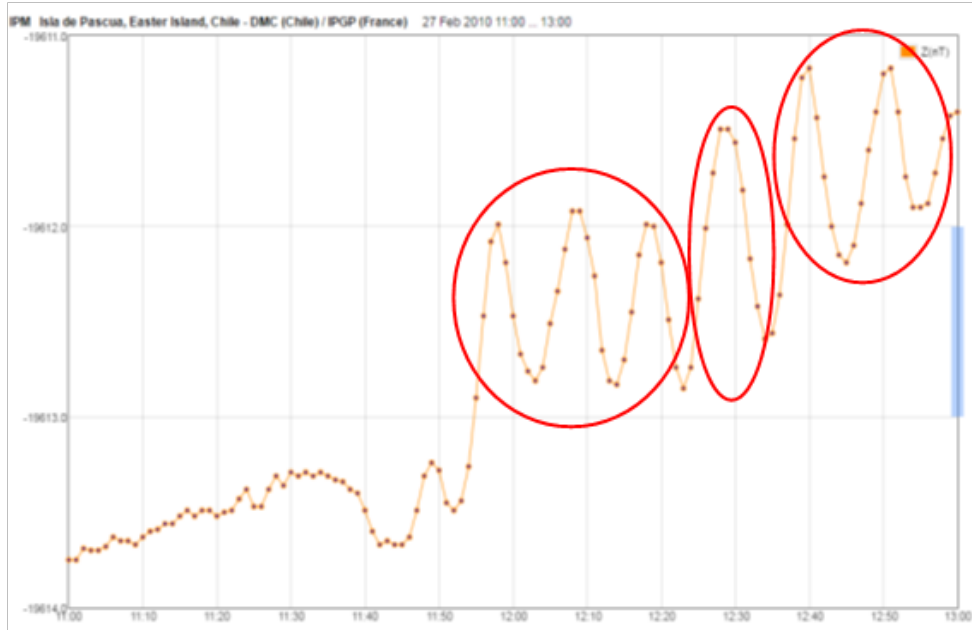
Different from the 2010 Chilean case in which tsunami propagation was characterized by periodic signals, a giant tsunami triggered by the 2011 Tohoku tsunamigenic earthquake demonstrated a traveling *solitary wave*. This is seen in Figure 3 within time interval 6:45–7:45 UTC, where a significant increase in the variation of the vertical signal is estimated to be  $b_z \approx 15.8$  nT (red circle in Figure 3). This is in good

agreement with theoretical prediction for the magnetic anomaly of  $b_z$  based on *frozen-flux* approximation, which gives  $b_z \approx 15.6$  nT (KAK in Table 1).

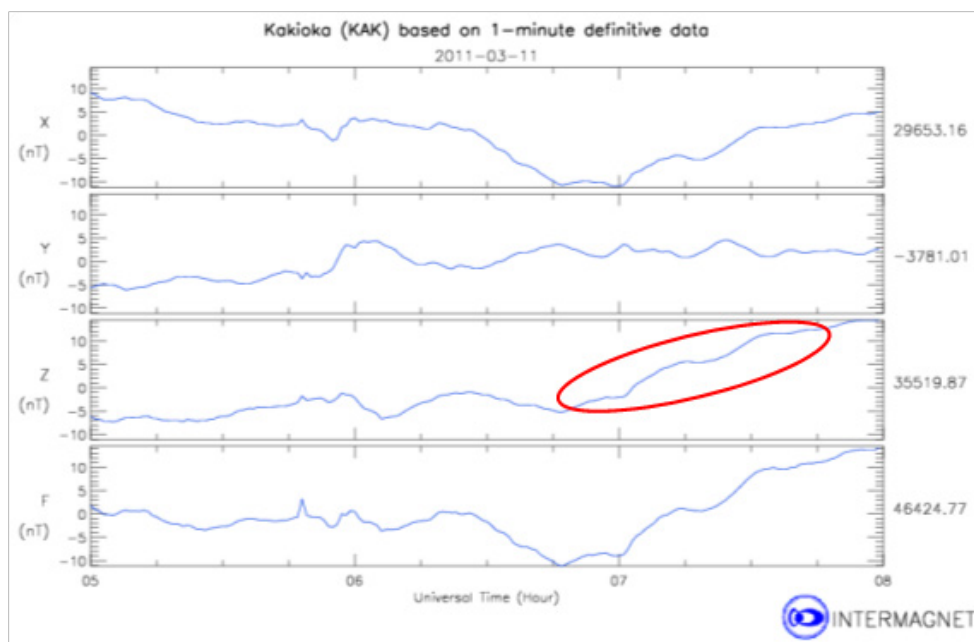
Analytical estimate dan visual inspection upon relevant magnetogram for the 2011 Tohoku event are consistent with field observations made by Ichihara *et al.* (2013) using magnetic instrument (OBEM) placed at the sea floor. They found that the vertical component  $b_z$  of the tsunami-magnetic signals varied in the range  $b_z \approx 12$ -19 nT with the mean value of  $b_z \approx 15.5$  nT (see Figure 4).

In addition to good agreement with relevant previous work (Ichihara *et al.*, 2013; Zhang, Baba, Liang, Shimizu, & Utada, 2014), the research results in this study are also confirmed by the findings of Minami & Toh (2013), reporting impulsive signals of the vertical component variation  $b_z$  with the amplitude of about 3 nT. The signal was detected by electromagnetometer sinking at the sea floor in the North-West Pacific (NWP) *site* 1500 km away from the epicenter. The earthquake induced a devastating tsunami, hitting areas off the east coast of Tohoku on 11 March 2011.

Significant discrepancies in  $b_z$  between the value of  $b_z = 3$  nT (Minami & Toh, 2013) and the ones of  $b_z = 15.6$  nT (analytical estimate based on *frozen-flux* approximation with the



**Figure 2.** Magnetogram from BCMT for the 2010 Chilean tsunami occurrence recorded at IPM (3500 km away from the epicenter) after 5-hours travelling from the epicenter towards IPM.



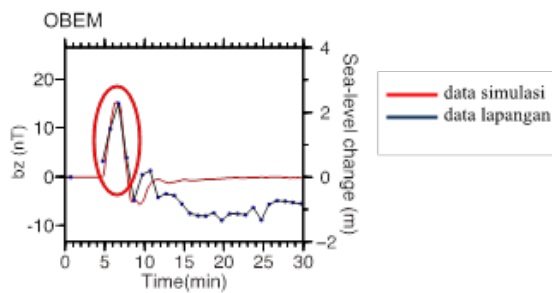
**Figure 3.** Magnetogram from INTERMAGNET for the 2011 Tohoku tsunami recorded at KAK (320 km away from the epicenter) within 1-hour travelling from the epicenter.

data from stasiun KAK) and  $b_z = 15.8$  nT (visual estimate based on magnetogram from INTERMAGNET) are due to the difference in observational locations. A simple calculation performed with respect to the geographical positions of magnetic instrument at the NWP site (Minami & Toh, 2013), B14 (Ichihara *et al.*, 2013), and KAK as well yields the mean value of  $b_z \approx 2.9$  nT for the 2011 Tohoku event, consistent with

the result of Minami & Toh (2013).

Figure 4 proves the maximum amplitude achieved for real time-varying of the vertical component  $b_z$  to be proportional to its corresponding sea surface elevation  $\eta$  monitored by a tsunami-gauge meter in the west Pacific (managed by NOAA) near the earthquake epicenter that generated Tohoku catastrophe. The proportionality between the two variables sup-

ports both theoretical estimates of  $b_z$  based on either *frozen-flux* approximation as predicted by equation (2) or calculation with the inclusion of diffusion effects as given by equation (4). The horizontal axis measured in minutes in Figure 4 below shows running time measured from earthquake OT. A high level of similarity is found in the variation of  $b_z$  between simulation on the basis of electromagnetic induction concept and *in situ* observations, particularly at tsunami onset time. This is clearly seen when the amplitude of the impulsive tsunami signal achieves its maximum value as shown by the red circle in Figure 4.



**Figure 4.** Time-varying of the vertical component  $b_z$  of the tsunami-magnetic field and its corresponding sea level change  $\eta$  from the 2011 Tohoku event recorded by B14, one of OBEM at the sea floor (250 km away from the epicenter), where  $b_z \approx 15.5$  nT (taken from Figure 4, Ichihara *et al.*, 2013).

Theory of motional induction at seas describes not only the change in the vertical component  $b_z$  of the secondary magnetic signals relative to the primary geomagnetic field  $F_z$  but also the variations in the horizontal component  $b_H$  due to tsunami. In the context of time-varying of  $b_z$  two equations generally needed to estimate  $b_z$  are the one given by equation (2) used when horizontal advection is assumed to be the dominant process, widely known as *frozen-flux* approximation and the other given by equation (4) used when diffusion is somewhat important. In the context of time-varying of  $b_H$  the only formula for use in determining its maximum amplitude is given by equation (3) that holds for cases both with *frozen-flux* and with no *frozen-flux* approximation.

The followings are simple analyses related to equation (3). Firstly, replacing  $i$  with  $i = \exp(i\pi/2)$  and then writing the dependence of both  $b_z$  and  $b_H$  upon time  $t$  as

$$b_z = b_{oz} \exp(-i \omega t) \quad (5)$$

$$b_H = b_{oH} \exp(-i \omega t) \quad (6)$$

where  $b_{oz}$  and  $b_{oH}$  represent maximum

amplitudes for the vertical  $b_z$  and horizontal  $b_H$  components, respectively. Secondly, substituting equations (5) and (6) as well as  $i = \exp(i\pi/2)$  into equation (3) yields

$$b_{oH} \exp(-i \omega t) = b_{oz} \exp\{-i(\omega t - \pi/2)\} \quad (7)$$

Equation (7) clearly shows a phase difference in the tsunami-magnetic signals between  $b_z$  and  $b_H$ , where the horizontal signal  $b_H$  leads to the vertical signal  $b_z$  by  $\pi/2$ . As fluctuation of the secondary magnetic field is in the form of harmonic function of period  $T$ , the phase lag between the two signals is equal to the time interval  $T/4$  required to achieve the maximum amplitude for each signal, with the horizontal component  $b_H$  achieves its maximum before the vertical component  $b_z$  does.

Within the context of the above mathematical analyses,  $T$  denotes the period of a tsunami wave that could be determined by simple uniform motion of the wave along its path. Some typical parameters needed to estimate  $T$  include the ocean depth of  $h \sim 5000$  m = 5 km, the tsunami phase speed of  $c = (gh)^{1/2} \sim 200$  m/s = 720 km/h, and the tsunami wavelength of  $\lambda \sim 120$  km. Taking these parameters all together, we have  $T \sim 10$  minutes.

Figure 5 gives observational records for the horizontal  $b_H$  and vertical  $b_z$  of the secondary signals monitored by four magnetic instrument at the sea floor discussed in Zhang *et al.* (2014). All instrument named NM02, NM04, NM01, and NM05 and positioned at various locations with respect to the epicenter of the earthquake generating the 2011 Tohoku tsunami clearly indicate that the horizontal component  $b_H$  (represented by the dominant signal  $b_y$  in Figure 5) achieves its first peak before the vertical signal  $b_z$ . The  $b_y$  signals were respectively recorded at NM02, NM04, NM01, and NM05: 60 minutes, 64.44 minutes, 68.33 minutes, and 72.78 minutes whereas the  $b_z$  signals were observed at NM02, NM04, NM01, and NM05: 62.78 minutes, 66.67 minutes, 70.56 minutes, and 75.56 minutes, respectively, both records after *tsunami onset time* at 05:46 UTC. Based on the estimated arrival time difference between  $b_y$  and  $b_z$  signals at the accounted four stations (NM02, NM04, NM01, NM05), then the averaged arrival time difference for the two signals ( $b_y$  and  $b_z$ ) to achieve their associated peak is about 2.5 minutes, in good agreement with  $T/4$ . This gains support from the work of Ichihara *et al.* (2013) stating that the dominant part of the horizontal component  $b_H$  is of  $b_y$  ( $b_y$  signal dominates over  $b_x$  signal as  $b_x$  signal is relatively weak) for the Tohoku event and that

the leading signal  $b_y$  precedes  $b_z$  by  $\sim 2$  minutes.

The two large tsunamis, the 2010 Chilean and the 2011 Tohoku events, occurred at places of relatively deep waters with  $h \geq 5100$  m such that  $h/L \geq 2.0$  because of  $L = 2.53$  km (Minami *et al.*, 2015). The ratio of  $h/L \geq 2.0$  is correlated with  $c/c_s \approx 1$  (see Table 2). The data provided in Table 2 suggest that the deeper the ocean the larger the ratio of  $c/c_s$ . In other words, horizontal advection is stronger in places where the ocean is adequately deep and dominates over diffusion effects in the deep sea and therefore *frozen-flux* theory is effective for use to estimate  $b_z$  in such places. However, the effects of diffusion become unignorable in shallow waters where  $h/L \leq 2.0$  (for example, the Indonesian waters). For cases where diffusion effects play a role in the dynamics of tsunami-magnetic signal generation, estimate of  $b_z$  is performed using equation (4) whereas estimate of  $b_H$  is still calculated using equation (3).

Table 3 below gives an example of the Mentawai tsunami that occurred on 25 October 2010 with the epicenter is located at  $3.48^\circ$  S and  $100.14^\circ$  E, tsunami OT at 15:00 UTC, and magnitude of  $M_w$  7.8, where the depth of observational locations varies from relatively shallow to deep waters.

The data listed in Table 3 clearly show the ratio of  $h/L < 2.0$  and  $c/c_s < 0.9$  for the first four observational locations. The role of diffusion effects decreases much with increasing both  $h/L$  and  $c/c_s$  found in deep-sea places. For Cocos Island in the western Australian waters and Enggano in Bengkulu, the dominant process is advection and thus estimates of  $b_z$  in the two areas utilize the *frozen-flux* theory as predicted by equation (2) or the incorporation of oceanic diffusion effects into prediction as given by equation (4).

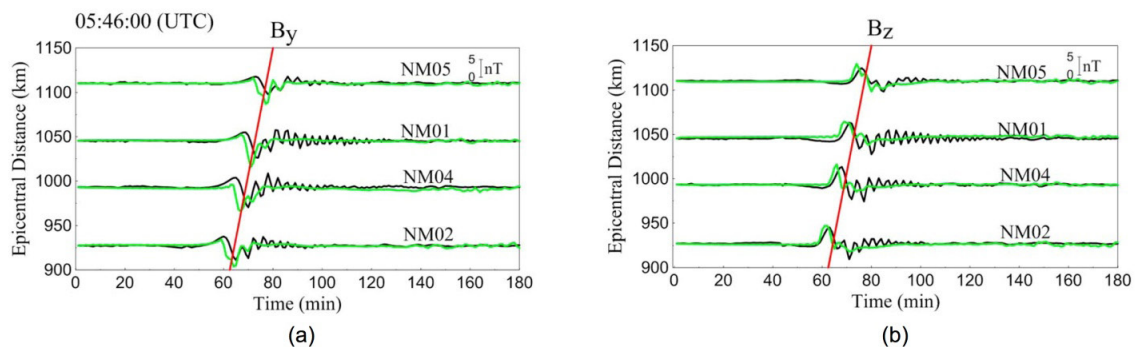
Observational location at Teluk Dalam in which the ratio of  $h/L = 0.3$  and  $c/c_s = 0.15$  indicates that a strong diffusion process is on duty. This is confirmed by a large deviation of  $b_z$  at a value of 84% from its true value based on calculation using equation (4).

Observational locations in Padang, Port Louis, and Rodrigues satisfy  $0.5 \leq h/L \leq 2.0$  such that measurements of  $b_z$  are classified into *intermediate regime* (Minami *et al.*, 2015). For Rodrigues,  $h/L = 1.3$  and  $c/c_s = 0.83$  the calculated value of  $b_z$  using equation (2) deviates from that when it is calculated using equation (4) by 17%. Such deviation reflects a dynamical balance between advection and diffusion.

The last two locations monitoring the Mentawai case in Table 3 demonstrate the

**Table 3.** Data for the 2010 Mentawai tsunami with  $b_z$  is calculated using equation (4).

Tsunami Event	Observational Location	$h$ (m)	$h/L$	$c$ ( $\text{ms}^{-1}$ )	$c_d$ ( $\text{ms}^{-1}$ )	$c_s$ ( $\text{ms}^{-1}$ )	$c/c_s$	$b_z$ ( $\text{nT}$ )
2010 Mentawai	Teluk Dalam	732	0.3	84.7	543.8	550.4	0.15	0.37
	Padang	1882	0.7	135.8	211.5	251.4	0.54	1.67
	Port Louis	2864	1.1	167.5	139.0	217.7	0.77	1.95
	Rodrigues	3261	1.3	178.8	122.1	216.5	0.83	2.15
	Cocos Island	6187	2.4	246.2	64.3	254.5	0.97	1.03
	Enggano	6699	2.6	256.2	59.4	263.0	0.97	0.71



**Figure 5.** (a) The  $b_y$  signal representing the horizontal component  $b_H$  and (b) the vertical component  $b_z$  of the secondary magnetic field owing to tsunami for the 2011 Tohoku event recorded by four ocean bottom magnetometers named NM02, NM04, NM01, and NM05 (taken from Figure 1, Zhang *et al.*, 2014).



dominance of horizontal advection over vertical diffusion as  $h/L \geq 2.0$  and  $c/c_s = 0.97$ . This confirms that estimate of  $b_z$  in the two locations was performed using *frozen-flux* approximation. The use of this approximation results in a small difference, of only 3%, in the calculation of  $b_z$  between the calculated value given by equation (2) and the one given by (4).

The data for  $b_z$  listed in Table 3 also show a systematic increase in the magnetic disturbance due to tsunami wave propagation, becoming stronger as it approaches the zonal boundary between diffusion and intermediate regimes, reaching its maximum disturbed condition where  $b_z$  achieves its maximum value of 2.15 nT observed in Rodrigues, undergoing weakening effects when penetrating into advection regime. This feature is well predicted by Minami *et al.* (2015).

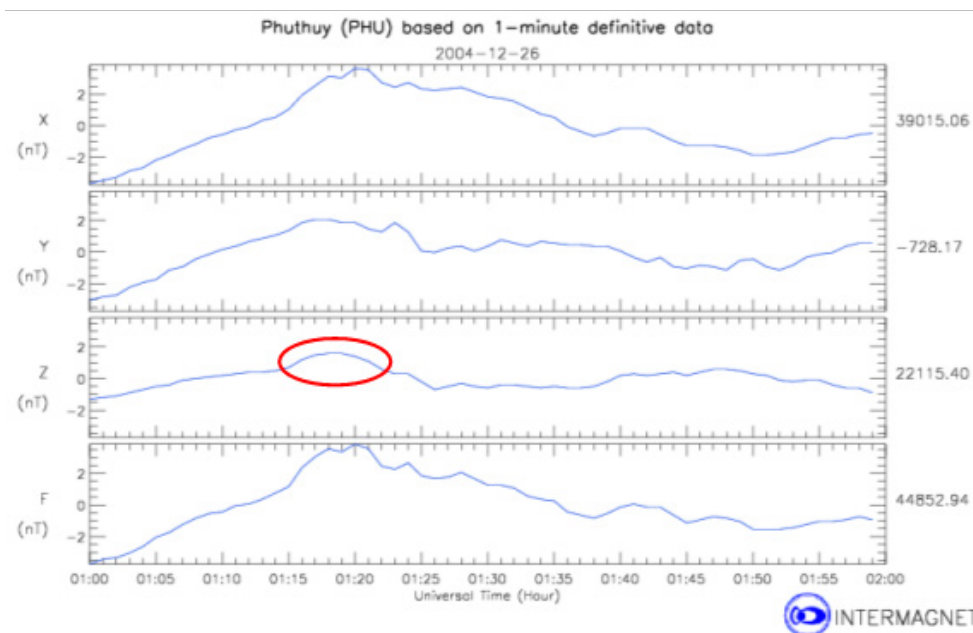
The results for  $b_z$  estimates reported in Table 3 vary from 0.37 nT to 2.15 nT, consistent with both field measurements and numerical simulations of the vertical component of tsunami-magnetic signals obtained for areas near the equator. Tyler (2005) and Klausner *et al.* (2011) found a value of  $b_z \leq 2,5$  nT for these areas.

However, the listed data in Table 3 for the 2010 Mentawai event confirm the maximum theoretical prediction for  $b_z$  based on *frozen-flux* theory that was proposed by Tyler (2005) after the most devastating tsunami hitting the west coast of Aceh in December 2004. The

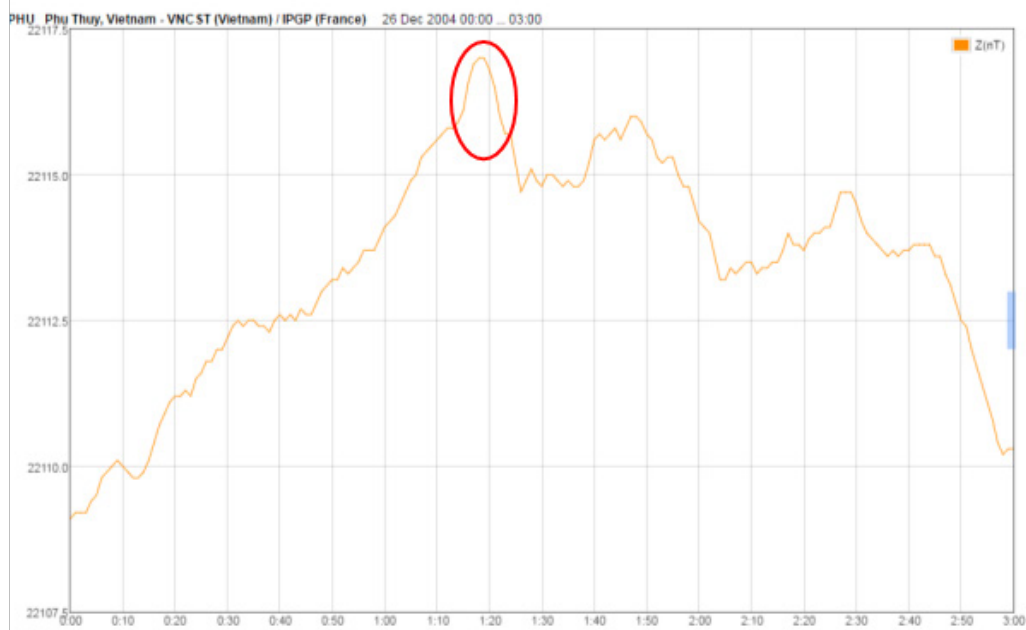
catastrophy tsunami was difficult to handle because there was no a well-developed, tsunami early warning system employed in the impacted areas, along the shorelines of Sumatranian west coast and surrounding the Indian Ocean. It was surprising that none of the local authority, such as BMKG nor global institutions, such as NGDC, NOAA and the Pacific Tsunami Warning Center (PTWC) managed instrument practically deployed for specific purposes on local deep sea research and regional sea surface monitoring in the Indian Ocean. Therefore, empirical data for local perturbations at the sea surface elevation  $\eta$  and ocean depth  $h$  are not available in these areas and hence analytical estimates of magnetic anomaly using equations (2), (3), and (4) cannot be performed. Contrary to this, visual estimates through inspection upon magnetogram for the case of Aceh tsunami remain available as given by both INTERMAGNET see in Figure 6 and BCMT seen in Figure 7.

Figure 6 describes local magnetic anomaly caused by earthquake having the hypocenter below the sea surface at depth. The magnitude of the earthquake is of  $M_w$  9.1 occurring on 26 December 2004 at  $3.4^\circ$  N and  $95.7^\circ$  E, and tsunami OT at 01:18 UTC. The red circle in Figure 6 shows *tsunami on-set* at 01:15 UTC.

Figure 7 provides magnetogram from BCMT for the same case as that in Figure 6, where PHU is located at  $21.3^\circ$  N and  $105.95^\circ$



**Figure 6.** Magnetogram from INTERMAGNET for the 2004 Aceh occurrence recorded at PHU (Vietnam), showing  $b_z \approx 1.8$  nT at the maximum amplitude of the tsunami-magnetic signal achieved.



**Figure 7.** Magnetogram from BCMT for the 2004 Aceh occurrence recorded at PHU (Vietnam), showing  $b_z \approx 2.0$  nT at the maximum amplitude of the tsunami-magnetic signal achieved.

E and confirms that the maximum amplitude of the vertical component  $b_z$  is found to be  $b_z \approx 2.0$  nT (denoted by red circle), which was recorded within time interval 1:13–1:22 UTC, consistent with time interval observed for the same event provided by INTERMAGNET. The data records at PHU given by instrument managed by INTERMAGNET and BCMT are also in good agreement with magnetogram measured by similar instrument in AAE (Ethiopia) located at  $9.02^\circ$  N and  $38.77^\circ$  E, where  $b_z \approx 2.5$  nT. The measured value of  $b_z \sim 2$  nT obtained from the two stations is supported by the work of Klausner *et al.* (2011) using *wavelet* computational techniques.

Having analyzed the generation of secondary magnetic signals and local anomaly in the vertical  $b_z$  and horizontal  $b_H$  owing to tsunami passages for four large tsunami events, namely: the 2010 Chilean, the 2011 Tohoku, the 2010 Mentawai, and the 2004 Aceh with large, sea-hypocentered earthquakes and magnitudes of  $M_w \geq 7.8$ , some crucial points of views are discussed in the following paragraphs.

Firstly, the intensity of local anomaly signal is relatively small compared to the one produced by the Earth's fluid outer core, termed as the main geomagnetic field (Prastowo & Jannah, 2015). Therefore, the design and development of sensitive electromagnetic sensors for field monitoring and measurements of magnetic fields induced by ocean flow is a must. This is important because the success of real-

time monitoring of any phenomenon in nature generally relies much on instrument accuracy and sensitivity. Hence, the advance of science and modern technology relevant to a particular earth-related disaster, such as tsunamigenic earthquakes and tsunamis, allows us to improve both the quality of measurement facilities for a better early warning system and the effectiveness of an approach to hazard mitigation study (Satriano *et al.*, 2011; Satake, 2014).

Secondly, real-time monitoring of tsunami-magnetic signal and its corresponding local anomaly in the oceans examined in this study can therefore be an alternative method of the existing tsunami early warning system. This existing method has been based on seismic monitoring, for example, instrument for field measurements of seismic activities utilizing Global Positioning System (GPS) to rapid analyses of the earthquake size (Blewitt, Kreemer, Hammond, Plag, & Stein, 2006). Current studies relying upon seismic signal monitoring has included examination of subsurface seismo-tectonic activities covering areas in Sumatra (Santosa, 2012) and evaluation of accuracy in determination of some earthquake parameters for improvement of Ina-TEWS performance (Madlazim & Prastowo, 2016). Compared to these studies, the present method used in this study is promising and excellent in the sense that the developed method of tsunami-magnetic signal estimates, as predicted by equations (2) and (4), directly relates to a tsunami parameter,

that is,  $\eta$ , representing the maximum vertical sea surface displacement due to the passage of a tsunami wave at open seas. Knowledge of disturbance in the sea surface elevation  $\eta$  is required for better prediction of tsunami height (*water run-up*) when the giant wave approaches shorelines. Hence, this work is also important for hazard mitigation study.

Thirdly, in the context of hazard mitigation study a comprehensive approach is then necessary through careful handling on problems associated with 'front- (hulu) and end- (hilir)' user treatment and other relevant aspects as well. In the perspective of end-user treatment, information about the generation of tsunami-magnetic signals and magnetic anomaly could possibly be incorporated into school curricula through relevant educational and laboratory activities (Prastowo & Ain, 2015), and classroom activities on the basis of SETS and local wisdom (Rusilowati, Supriyadi, & Widiyatmoko, 2015). A combined approach of both types of treatment through integrated science in a classroom setting could also be implemented by providing students with discussions on mangrove plantation along a shoreline that is able to reduce ocean current and incoming wave energy hence to protect population living nearby (Kristiyanto, Armono, & Soemarno, 2013). In principle, efforts in reducing disaster risks to minimum are thus compulsory for all authorities including educators, scientists, engineers, and decision makers to do the best for minimizing risks of disaster and maximizing awareness of disaster-related science (Suppassri *et al.*, 2015).

## CONCLUSIONS

Tsunami waves caused by large earthquakes with the hypocenter located below the sea surface generate secondary magnetic signals hence anomalies observed as small perturbations on the primary, Earth's magnetic fields. In this study, the secondary fields are then decomposed into the vertical  $b_z$  and horizontal  $b_H$  components and determined by analytical and visual estimates. Theoretical estimates of the two components depend on two interconnected parameters:  $h/L$  and  $c/c_s$ . If  $h/L \geq 2.0$  and  $c/c_s \approx 1$  hold (deep-sea cases with ignorable diffusion effects), then  $b_z$  is calculated using *frozen-flux* approximation. Using this approximation, estimate of  $b_z$  yields  $b_z = 0.43$  nT for the 2010 Chilean event and  $b_z = 15.31$  nT for the 2011 Tohoku occurrence. Values of

$b_z$  found for the two large tsunamis are in good agreement with magnetogram from both INTERMAGNET and BCMT, where  $b_z = 0.47$  nT for the 2010 Chilean case and  $b_z = 15.80$  nT for the 2011 Tohoku tsunami. Another important result is that the horizontal signal  $b_H$  reaches at its maximum peak at about 2.5 minutes before the vertical signal  $b_z$  does.

The 2010 Mentawai event occurred in a relatively shallow water and is unique in that the roles of diffusion effects become into play. Some observational points show a large deviation of  $b_z$  estimates from the expected values, suggesting that prediction of  $b_z$  based on the *frozen-flux* theory is inapplicable to cases where oceanic diffusion is strong. However, the scatter of the calculated value for  $b_z$  in the range of  $b_z \leq \pm 2.5$  nT for this case is consistent with  $b_z \sim 2$  nT recorded by magnetogram from INTERMAGNET and BCMT for the 2004 Aceh tsunami.

Monitoring of magnetic signals and anomalies due to tsunami can therefore be a candidate for tsunami early warning to assign a more comprehensive system in cooperation with the existing method based on seismic signal processing and monitoring. Good estimates of  $b_z$  and  $b_H$ , in agreement with prediction by visual inspection on magnetogram and the results from relevant previous work, however, have not yet unveiled the characteristic of tsunami wave propagation. Issues, such as tsunami height when approaching the shoreline, tsunami propagation direction and its associated speed at open seas remain important and therefore such issues become challenging for future work.

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## REFERENCES

- BCMT (2016). Data Plot. [http://www.bcmt.fr/data\\_plot.php](http://www.bcmt.fr/data_plot.php). Accessed on 20-21 April 2016.
- Blewitt, G., Kreemer, C., Hammond, W.C., Plag, H., & Stein, S. (2006). Rapid determination of earthquake magnitude using GPS for tsunami

- warning systems. *Geophysical Research Letters*, 33, 1-4.
- IAGA (2016). Model field at a point by IGRF (IGRF-12). International Geomagnetic Reference Field/World Data Centre (IGRF/WDC) <https://www.ngdc.noaa.gov/IAGA/vmod/igrf.html> linked to <http://wdc.kugi.kyoto-u.ac.jp/igrf/point/index.html>. Accessed on 27 March 2016 and 18 April 2016.
- Ichihara, H., Hamano, Y., Baba, K., & Kasaya, T. (2013). Tsunami source of the 2011 Tohoku earthquake detected by an ocean-bottom magnetometer. *Earth and Planetary Science Letters*, 382, 117-124.
- INTERMAGNET (2016). Data-Plotting Service. <http://www.intermagnet.org/data-donnee/dataplot-eng.php?type=xyz>. Accessed on 20-21 April 2016.
- Klausner, V., Domingues, M. O., Mendes, O., & Papa, A. R. R. (2011). Tsunami effects on the Z component of the geomagnetic field. August 25, 2011. physics.space-ph physics.aoph arXiv:1108.4893v1.
- Klausner, V., Kherani, E. A., & Muella, M. T. A. H. (2016). Near- and far-field tsunamigenic effects on the Z component of the geomagnetic field during the Japanese event, 2011. *Journal of Geophysical Research*, 121, 1772-1779.
- Kristiyanto, A., Armono, H. D., & Soemarno. (2013). Kemampuan hutan mangrove rumpun Rhizophora SP dan Avicennia SP dalam meredam gelombang laut. *Jurnal Pendidikan Fisika Indonesia*, 9(2), 173-183.
- Madlazim & Prastowo, T. (2016). Evaluation of earthquake parameters used in the Indonesian tsunami early warning system. *Earthquake Science*, 29(1), 27-33.
- Manoj, C., Maus, S., & Chulliat, A. (2011). Observation of magnetic fields generated by tsunamis. *EOS*, 92(2), January 11, 2011, 13-14.
- Minami, T., & Toh, H. (2013). Two-dimensional simulations of the tsunami dynamo effect using the finite element method. *Geophysical Research Letters*, 40, 4560-4564.
- Minami, T., Toh, H., & Tyler, R. H. (2015). Properties of electromagnetic fields generated by tsunami first arrivals: classification based on the ocean depth. *Geophysical Research Letters*, 42, 2171-2178.
- NGDC (2016). Bathymetric Data Viewer. National Centers For Environmental Information/ National Geophysical Data Center (NCEI/NGDC) <https://maps.ngdc.noaa.gov/viewers/bathymetry/>. Accessed on 27 March 2016 and 18 April 2016.
- NOAA (2016). Recent and Historical Tsunami Events and Relevant Data. Pacific Marine Environmental Laboratory/National Oceanic and Atmospheric Administration (PMEL/NOAA) [http://nctr.pmel.noaa.gov/database\\_devel.html](http://nctr.pmel.noaa.gov/database_devel.html). Accessed on 27 March 2016 and 18 April 2016.
- Prastowo, T. & Ain, T. N. (2015). Percobaan *gravity current* untuk menguji konsep hidrodinamika dan hukum kekekalan massa pada fluida inkompresibel. *Jurnal Pendidikan Fisika Indonesia*, 11(1), 84-92.
- Prastowo, T., & Jannah, A. (2015). Estimates of the earth's liquid outer core velocity using toroidal assumption and the DGRF/IGRF 1990-2000 magnetic models. *Proceedings of International Conference on Science and Science Education (IConSSE)*, Faculty of Science and Mathematics (FSM), Satya Wacana Christian University (SWCU), August 1, 2015.
- Rusilowati, A., Supriyadi, A., & Widiyatmoko. (2015). Pembelajaran kebencanaan alam berbunyi SETS terintegrasi dalam mata pelajaran Fisika berbasis kearifan lokal. *Jurnal Pendidikan Fisika Indonesia*, 11(1), 42-48.
- Santosa, B. J. (2012). Seismogram analysis of earthquakes in Sumatra-Java at HYB observatory station. *Jurnal Pendidikan Fisika Indonesia*, 8(2), 195-202.
- Satake, K. (2014). Advances in earthquake and tsunami sciences and disaster risk reduction since the 2004 Indian ocean tsunami. *Geoscience Letters*, 1(15), 1-13.
- Satriano, C., Wu, Y. M., Zollo, A., & Kanamori, H. (2011). Earthquake early warning: concepts, methods, and physical grounds. *Soil Dynamics and Earthquake Engineering*, doi:10.1016/j.soildyn.2010.07.007.
- Sugioka, H., Hamano, Y., Baba, K., Kasaya, T., Tada, N., & Suetsugu, D. (2014). Tsunami: ocean dynamo generator. *Scientific Report on www.nature.com*. 4: 3596, 1-7.
- Suppasri, A., Goto, K., Muhari, A., Ranasinghe, P., Riyaz, M., Affan, M., Mas, E., Yasuda, M., & Imamura, F. (2015). A decade after the 2004 Indian Ocean Tsunami: the progress in disaster preparedness and future challenges in Indonesia, Sri Lanka, Thailand and Maldives. *Pure and Applied Geophysics*, 172, 3313-3341.
- Tatehata, H., Ichihara, H., & Hamano, Y. (2015). Tsunami-induced magnetic fields detected at Chichijima Island before the arrival of the 2011 Tohoku earthquake tsunami. *Earth, Planets and Space*, 67, 185-195.
- Tyler, R. H. (2001). On the theory of magnetic fields generated by planetary oceans, *Proceedings of The Third Conference on Marine Electrodynamics (MARELEC)*, Spearhead Exhib. Stockholm, Sweden.
- Tyler, R. H. (2005). A simple formula for estimating the magnetic field generated by tsunami flow. *Geophysical Research Letters*, 32, L09608, 1-4.
- Wang, B., & Liu, H. (2013). Space-time behaviour of magnetic anomalies induced by tsunami waves in open ocean. *Proceedings of The Royal Society A*. 469, 1-17.
- Zhang, L., Baba, K., Liang, P., Shimizu, H., & Utada, H. (2014). The 2011 Tohoku tsunami observed by an array of ocean bottom electromagnometers. *Geophysical Research Letters*, 41, 1-9.

## SCIENCE LITERACY INDICATORS IN OPTICAL INSTRUMENTS OF HIGHSCHOOL PHYSICS TEXTBOOKS CHAPTER

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### ABSTRACT

The direction of current science is emphasized on the importance of science literacy skill as a preparation for students returning to community after finishing school. Science literacy skill is believed can help the individuals to solve the problem scientifically and accountable. Science textbooks are instructional tools that help students learning science. The purpose of this research is to analyse the textbooks of Physics for high school grade X about Optical Instruments topic based on science literacy indicator. The study conducted in four senior highschoools. There were two textbooks used in those schools, Book A and Book B. The results showed that on average the emergence of science literacy indicator of science nomenclature was 17.5%, intellectual process skills was 45.5%, the rules of scientific evidence was 8.5%, postulate of science was 19%, and scientific disposition was 9.5%. Book A contained of more research activities than Book B, but Book B linked the second indicator more comprehensive. The advantages and disadvantages of each analyzed textbooks can be used as a further background study for developing the good quality teaching material of physics-based scientific literacy.

### ABSTRAK

Arah dalam pembelajaran sains saat ini menekankan pentingnya kemampuan literasi sains sebagai persiapan untuk terjun ke dalam masyarakat setelah menyelesaikan studi. Kemampuan literasi sains diyakini dapat membantu individu untuk menyelesaikan masalah yang dihadapi secara ilmiah dan bisa dipertanggungjawabkan. Buku ajar merupakan suatu alat pengajaran yang membantu siswa dalam memahami sains. Tujuan penelitian ini adalah menganalisis buku teks fisika SMA/MA Kelas X materi alat optik berdasarkan indikator literasi sains. Penelitian dilakukan di empat sekolah menengah atas. Terdapat dua buku yang digunakan di sekolah tersebut, Buku A dan Buku B. Hasil penelitian menunjukkan bahwa rata-rata kemunculan indikator literasi sains penamaan ilmiah 17,5%, kemampuan eksperimen dan observasional dasar 45,5%, kaidah bukti saintifik 8,5%, postulat sains 19%, dan disposisi ilmiah 9,5%. Buku A mengandung kegiatan penyelidikan lebih banyak dibandingkan Buku B, namun Buku B mengaitkan indikator literasi sains yang kedua lebih komprehensif. Kelebihan dan kekurangan dari masing-masing buku dapat dijadikan dasar penelitian lebih lanjut untuk meningkatkan kualitas pembelajaran berbasis literasi sains.

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**Keywords:** optical instruments; science literacy; textbooks

### INTRODUCTION

The main purpose of current Physics learning is to prepare the students for their better future in 21st century (Karelina, A. & Etkina,

E., 2007). In order to fulfill the purpose, Physics learning should be able to help the students to develop the abilities to struggle for their bright future (Etkina et al., 2006). The students are demanded to be able to solve complex problems using media, technology, information, and communication for their life and future career. They are also expected to use the logical and

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accountable scientific reasoning in their daily life.

Comprehension and application of science for society needs in solving the problem is the definition of science literacy (Hurd, 1997; Holbrook & Rannikmae, 2009; Gormally, Brickman, & Lutz, 2012). Development of science framework revealed that having science attitudes as students behavior is the main purpose of science learning. The students are trained to have abilities in applying the competences of science which they learned from school to become well behavior persons in society and vice versa they can utilize the society and environment as a learning source to become more wise people in making decision of their life.

The measurement of science literacy skill has been done in many countries. One of the routine programme of measurement of science literacy skill which is done once in 3 years is Program for International Student Assessment (PISA). From the report of PISA 2015, the average score of science literacy of Indonesian students was 403 and in the rank of 62 from 70 countries of test participants. Research from Arief & Utari (2015) has reported the same result. They used levels of inquiry approach in students' learning program of grade VII to improve students' science literacy. The result of the research revealed that by applying inquiry approach, the competence of explaining scientific phenomenon and the competence of interpreting data were significantly increase. However, the competence of evaluating and designing scientific investigation were still poor. Nevertheless, actually there is a potensial showed by the students to become increase those competence by special training which is accordance that can be done in future study.

Two main factors that influenced students' science literacy are the learning resources (e.g. book) and the learning program that support them to have science literacy skills (Rusilowati, Susilowati, & Nugroho, 2016). The fact showed that students have more time to interact with the textbook than with the teacher. Having this flexibility, there is a chance to train them to have science literacy skill by optimizing the textbook function. But of course there is a requirement for the textbook to bridge the students to have good science literacy skill by enriching the textbook with research activities to develop students scientific abilities. Therefore, the content of textbook for students should be the main consideration.

Many researches about science literacy

skill development were done. One of the developments is in the used of indicator of science literacy. Nature of Scientific Literacy Test (NOSLiT) is an instrument measuring the students' comprehension of authentic science to reach the success of science literacy (Wenning, 2006). NOSLiT is developed especially to measure the science literacy of senior high school students. Thus, the indicators of science literacy skill used by NOSLiT are suitable with the thinking ability of senior high school students. The indicators are science nomenclature, intellectual process skills, rules of scientific evidence, postulate of science, scientific disposition, and major misconceptions about science.

The research procedures that will be done are adapted from science literacy indicators stated by Wenning (2006). The first adaptation is the use of five from six science literacy indicators, diminution of one indicator is about the major misconceptions about science. The second adaptation is diminution of the third criteria of indicator, the rules of scientific evidence. From 12 criterias there will be only 4 criterias which will be used. This is chosen because the consideration about the discussion of science misconceptions consists of complexity and needs a separated discussion. Then, the reason to not use the other 9 criterias in the indicators of the rule of scientific evidence is because it consists of complexity which can not be seen directly from the textbook.

To get the preliminary data about misconception on optical instruments topic which hold by the students, interview session were done with some students in Pacet subdistrict. Based on interview results, optical instruments was difficult to be learned because it was delivered using mathematic equations. Since, they did not understand the concepts behind the mathematic equations, it results misconception among them. Other researches also reported difficulties in understanding the topic. Suniati et al. (2013) explained that the students had a misconception in defining properties and magnification of images on the magnifying glass. Agnes et al. (2015) stated that most of students in her research samples had misconception in analyzing the formation of image on the mirror and optics devices. From the preliminary data and other researchers report, it can be concluded that there is a need to do a crucial effort in revising and correcting the misconception in optical instruments topic. Therefore, the purpose of this research is to describe the contribution of the textbook in developing students science

literacy skills by analysing the Physics textbook for high school grade X on Optical Instruments topic based on the indicators of science literacy in Pacet subdistrict.

**METHOD**

This research was used descriptive method and conducted in all high schools in Pacet subdistrict, Mojokerto district in the odd semester in academic year 2016/2017. There are SMA N 1 Pacet, SMA 45 Pacet, MA Pacet, and MBI Amanatul Ummah as participants of this research.

The research subject was the Physics textbooks for grade X of Optical Instruments topic used by those four schools. There were two textbooks used, Book A and Book B. The analysis was done by using the indicator of science literacy skill setted by Wenning (2006). The analysis has been done based on the indicator of learning material arranged by the researchers. The indicators are adjusted with the rules of Optical Instruments on Curriculum 2013.

The data collection was used check-list technique on the analysis paper. The first step was analysed the indicator of science literacy, in every indicator of the optical instruments material from Book A. After giving the check-list, descriptions of the indicators that appears also need to be written. This part was repeated until five indicators of science literacy on arranged learning indicator had been analyzed.

The second step was analysed the science literacy indicators on every learning indicators of Optical Instrument material from Book B. After finished all books, the analysis result of science literacy was calculated it percentage by counting the number of indicators that appears and divide them with the total number of indicator then multiplied the result by one hundred percent. From the calculation, the emergence of science literacy of the books can be described.

**RESULTS AND DISCUSSION**

Based on the analysis, the content of both of the books on the Optical Instruments material had similar learning indicators. In this chapter, the materials discussed from Book A and Book B were Human Eyes, Visual Impairment, Magnifying Glass, Microscope, Telescope, and Camera. These materials were delivered in text and images forms. On Book A there

were additional rubric in form of links about the related information concepts taught. Students were expected to access the link independently or by group to get additional knowledge more than the content from the text Book A and also to train the students' skill in collecting data and information. Both of the books were also equipped by the example of problems and answers which can help students to understand the applied concept

The first analysis result from the research process is the analysis of science literacy indicators on every learning indicator. Not all of the learning indicators on the book which are analyzed contain of the science literacy indicators. Below are the results of the analysis.

**Table 1.** The analysis results of science literacy indicator in every learning indicator

Learning Indicators	The Emergence of Science Literacy Indicator	
	Book A	Book B
Identify parts of eye	1	1
Analyze the formation of images in the eyes	1	0
Identify optical instruments for visual impairment	0	0
Analyze image formation in eyes with impaired vision	1	1
Analyze formation of images on the magnifying glass	1	1
Identify microscope parts	2	1
Analyze formation of images on the microscope	5	1
Identify telescope parts	1	1
Analyze formation of images on the telescope	5	5
Analyze system of the eye and the camera	0	1
Analyse formation of images on the camera	0	0
Analyze the use of focal length and exposure time	0	0
Total	17	12

On Book A, the learning indicators 7 and 9 contain the most science literacy indicators. There are some analysis activities about microscope and telescope which can be done by the students to improve their scientific attitu-

des, understanding of concepts, and skills. That activities will integratively train the five science literacy indicators at once, such as science nomenclature, the intellectual process skills, rules of scientific evidence, postulate of science, and scientific disposition. Indicator 1, 2, 4, 5, and 8 only contain one indicator of science literacy because those indicators only show the intellectual process skills. That indicator appears in form of observing the picture from the textbook. Generally, the picture provides the students activity to observe the formation of images on some optic instruments. Indicator 6 shows two indicators of science literacy, there are science nomenclature and the intellectual process skills. The activity for students is to find the literature through the link provided and observe the parts of microscope and the formation of images in microscope through picture and link it with what they get from the website.

On Book B, the learning indicator 9 contain the most science literacy indicators. In this indicator there are research activity about telescope done by the students which is integratively train all five indicators of scientific literacy at once. The Indicator 1, 4, 5, 6, 7, 8, and 10 only contain of one indicator of science literacy. Those seven indicators only show the intellectual process skills. As in the Book A, the indicator is shown in form picture observation from the textbook.

Based on the analysis results above, it can be concluded that the emergence of scientific literacy indicator is mostly shown on the indicator 9, which is analyzing the form of images on the telescope. Both of the books have five scientific literacy indicators which are analyzed. The completeness of scientific literacy indicators in that learning indicator is packaged in exploratory activities. Book A used the exploratory activity to make a simple Galileo telescope meanwhile Book B used the exploratory activity through literature study about the space telescope, radio telescope, and simply measurement of the diameter of the moon.

The disappearance of complete science literacy indicator on the other learning indicator is because the material is presented in text form. Students are often exposed that science is a collection of concepts to be memorized rather than processes for information-seeking and evaluation (Zimmerman, 2007; Kuhn, 2010; Minner, Levy, & Century, 2010; Morris, Masnick, Baker, & Junglen, 2015). The books give the explanation directly related to the material without providing an opportunity for stu-

dents to engage in activities that construct their understanding. Most of the indicators in optical instruments material are taught by reading and writing only.

The second result of the analysis from the research is the analysis of science literacy indicator from both of the books. Table 2 is the data of the analysis results from the science literacy indicators on Book A and Book B. Based on the analysis data in Table 2, both of Book A and Book B have contained five science literacy indicators. On average, the highest percentage of science literacy indicator is the second indicator, it is 45.5%. Both of the books show the same result that the most dominant science literacy indicator is the second indicator which use the picture as a media to provide the students activity to do observation to get the learning concept. Another media which can be used for teaching the concepts are natural phenomenon, graph, or the environmental investigation.

The second literacy indicator that often arises is the science nomenclature by 17.5%. The science nomenclature is the general language used in science. The language is related with the experiment activity and the concept of epistemology. The textbooks that rich of science literacy uses the general scientific language that commonly used in science. The Book A has higher percentage of the science nomenclature indicator than Book B. Eventhough the material of Book A is lesser than Book B, but Book A is richer in the use of scientific language.

The third literacy indicator that often arises is postulate of science by 19%. In this indicator, Book A has higher percentage than Book B. Postulate of science is the assumption about science which is still used until now. There are 8 indicators of postulate of science analyzed in the book. Postulate of science will be understood if only students do the activity that actively construct their comprehension of concepts taught. This is because the assumptions about science is closely related to the investigation or experimental activities. The Book A contains two exploratory activities while the Book B contains only one exploratory activities.

The fourth indicator that often arises is a scientific disposition by 9.5%. Scientific disposition is the character or attitude that is expected from a scientist. Scientists are people who learn about science so the students are also expected to have a scientific disposition indicator. These characters include curiosity and skepticism, objective, and not dogmatic,



**Table 2.** Data from the analysis of scientific literacy indicators in both books

Science Literacy Indicator (Wenning, 2006)	The Physics Textbook				Average (%)
	Book A (16 pages)		Book B (20 pages)		
	$\Sigma$ Statement	(%)	$\Sigma$ Statement	(%)	
Science nomenclature	14	20	8	15	17.5
Intellectual process skills	26	37	28	54	45.5
Rules of scientific evidence	6	9	4	8	8,5
Postulate of science	16	23	8	15	19
Scientific disposition	8	11	4	8	9.5
Total	70	100	52	100	100

creative and logical, as well as honest and trustworthy. Book A and Book B was different only about 3% on this indicator. In general, the two books have given indicators of scientific disposition to the students.

The last indicator that appears with the lowest percentage is the rules of scientific evidence by 8.5%. The rules of scientific evidence is treating the problems faced by students. The problems in the textbooks can be either a case study or the problem in exploratory activities. There are four criterias in this indicator which were analyzed in both textbooks. Indicators rules of scientific evidence has the lowest percentage since the second book presents many descriptions science knowledge without involving students about how the knowledge is acquired.

Based on the analysis, the second science literacy indicator is the highest appearance on both of the book. The second science literacy indicator on Book A does not relate to a mathematical equation, but only the physical concepts. On Book B, the second science literacy indicator is related to physical concepts which is going to be learned then relate it to applicable mathematical equation. For example the indicator to analyze the formation of images on a magnifying glass, the Book B associates images as a media observation to introduce the logic of mathematical equations of the obtained magnification image. The Book A invites students to analyze about the light rays in the process of forming an image without defining how the magnification can be obtained.

Thus, it can be concluded that Book A has more science literacy indicators than Book B. However, the second indicator, intellectual process skills in Book B is more comprehensive. Through Book A, skill of science literacy can be trained more optimal, but linkages with the concept of mathematical equations will be

more easily found in Book B.

The science textbook is a very important component in learning science in school (Chiappetta & Fillman, 2007). The students look the subject through the textbook that they read. Some Physics textbooks still give the mathematical equations without explaining it is obtained through the physical state of a scientific phenomenon. Therefore, the contents of physics teaching materials used need to be designed to improve students' perceptions and the logic of how a mathematical equation is applied and obtained.

One of the effort can be done is to engage students in exploratory activities. Exploratory activities will require students to track down a problem or issue of certain phenomena using complex skills, either using the mathematical and non mathematical approach. Exploratory activities will encourage students to be more critical and active, not just directly accept the concepts presented in textbooks. Through these activities, the learning processes invite students to observe, predict, investigate, analyze and conclude. The kind of activities that can be done such as experimental activities, observation, literature study, as well as role play.

Those points are suitable with the objective of science literacy by Holbrook & Rannikmae (2009) that the excellent scientific literacy is taught with the view that "teaching through science" not "science through teaching". Currently, the direction in learning science emphasizes on the importance of scientific literacy as the ability to be owned by the students after learning (Fives, Huebner, Birnbaum, & Nicolich, 2014). There are many researches on students' science literacy assessment which has been done (for example Bybee, 2008; Wenning, 2006, 2007; Fives et al, 2014). Therefore, the learning process in school should support the development of students science literacy

skills and it can be done optimally by providing good physics textbook to encourage student to do many kind of activities such as experimental activities, observation, literature study, as well as role play.

### CONCLUSION

The emerging of science literacy indicators from the two textbooks sequentially are the intellectual process skill of 45.5%, postulate of science by 19%, science nomenclature of 17.5%, scientific disposition by 9%, and rules of scientific evidence 8.5%.

The science literacy indicators from Book A appears more often than Book B. Book A contains more activities of investigation than Book B, but Book B is linking the second indicator, the intellectual process skills with the more comprehensive concepts and mathematical equations.

The results of this study can be used by teachers of physics community to consider the textbook to be used. The textbooks used must contain with indicators of scientific literacy and have clear thinking groove in teaching physics concept. The advantages and disadvantages of each analyzed textbooks can be used as a further background study for developing the good quality teaching material of physics-based scientific literacy.

### REFERENCES

- Agnes, D., Kaniawati, I., & Danawan, A. (2015). Analisis Deskriptif Tes Tiga Tingkat Materi Optika Geometri dan Alat Optik. *Prosiding Simposium Nasional Inovasi dan Pembelajaran Sains 2015*. Bandung: Prodi Magister Pengajaran Fisika, FMIPA, ITB.
- Arief, M. K., Utari, S. (2015). Implementation of Levels of Inquiry on Science Learning to Improve Junior High School Student's Scientific Literacy. *Jurnal Pendidikan Fisika Indonesia*, 11 (2), 117-125.
- Bybee, R. W. (2008). Scientific literacy, environmental issues, and PISA 2006: The 2008 Paul F-Brandwein lecture. *Journal of Science Education and Technology*, 17, 566-585.
- Chiappetta, E. L., Fillman, D. A. (2007). Analysis of Five High School Biology Textbooks Used in Uneted States for Inclusion of the Nature of Sciences. *International Journal of Science Education*, 29 (15), 1847-1868.
- Etkina, E., Heuvelen, A. V., White-Brahmia, S., Brookes, D. T., Gentile, M., Murthy, S., Rosengrant, D., Warren, A. (2006). Scientific Abilities and Their Assessment. *Physics Education Research*, 2, 020103.
- Fives, H., Huebner, W., Birnbaum, A., Nicolich, M. (2014). Developing a Measure of Scientific Literacy for Middle School Students. *Science Education*, 98(4), 549-580.
- Gormally, C., Brickman, P., Lutz, M. (2012). Developing a Test of Scientific Literacy Skills (TO-SLS): Measuring Undergraduates' Evaluation of Scientific Information and Arguments. *CBE-Life Sciences Education*, 11, 364-377.
- Holbrook, J. & Rannikmae, M. (2009). The Meaning of Scientific Literacy. *International Journal of Environmental and Science Education*, 4(3), 275-288.
- Hurd, P. D. (1997). Scientific Literacy: New Minds for a Changing World. *Science Education*, 82, 407-416.
- Karelina, A. & Etkina, E. (2007). Acting like a physicist: Student approach study to experimental design. *Physics Education Research*, 3, 020106.
- Kuhn, D. (2010). Teaching and learning science as argument. *Science Education*, 94(5), 810-824.
- Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—What is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, 47(4), 474-496.
- Morris, B. J., Masnick, A. M., Baker, K., Junglen, A. (2015). An Analysis of Data Activities and Instructional Supports in Middle School Science Textbooks. *International Journal of Science Education*, 37 (16), 2708-2720.
- Organisation for Economic Cooperation and Develepment. (2016). PISA 2015 Results in Focus. Retrieved from <https://www.oecd.org/pisa/pisa-2015-results-in-focus.pdf>
- Rusilowati, A., Nugroho, S. E., Susilowati, S. M. E. (2016). Development of Science TextBook Based on Scientific Literacy For Secondary School. *Jurnal Pendidikan Fisika Indonesia*, 12 (2), 98-105.
- Suniati, N. M. S., Sadia, W., Suhandana, A. (2013). Pengaruh Implementasi Pembelajaran Kontekstual Berbantuan Multimedia Interaktif Terhadap Penurunan Miskonsepsi. *e-Journal Program Pascasarjana Universitas Pendidikan Ganesha*, 4.
- Wenning, C. J. (2006). A framework for teaching the nature of science. *Journal of Physics Teacher Education*, 3(3).
- Wenning, C. J. (2007). Assessing Inquiry Skills as Component of Scientific Literacy. *Journal of Physics Teacher Education*, 4(2), 21-24.
- Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. *Developmental Review*, 27(2), 172-223.

## INTERACTIVE MULTIMEDIA THERMODYNAMICS TO IMPROVE CREATIVE THINKING SKILL OF PHYSICS PROSPECTIVE TEACHERS

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### ABSTRACT

This study aims to improve the creative thinking skills of prospective physics teacher as the impact of the application of interactive thermodynamics multimedia (ITMM). The research method used is quasi experiment with control group pretest-posttest design. The subjects consisted of 34 students in the experimental group and 33 students in the control group. Participant students are physics physics semester fourth, in one of the state universities in East Kalimantan. The research instrument consists of multiple choice test items charged with creative thinking skills. Data were analyzed by using difference test of two averages. The normalized gain score  $\langle g \rangle$  of creative thinking skill aspect on the experimental group is 0.60 and the control group is 0.31. This indicates that the creative thinking skills of the prospective physics teacher increase significantly after they experience thermodynamic learning with interactive multimedia. Thus it can be concluded that the use of interactive multimedia improve the creative thinking skills of prospective physics teachers.

### ABSTRAK

Penelitian ini bertujuan untuk meningkatkan keterampilan berpikir kreatif mahasiswa calon guru fisika sebagai dampak penerapan multimedia interaktif termodinamika (MMIT). Metode penelitian yang digunakan adalah kuasi eksperimen dengan *control group pretest-posttest design*. Subjek penelitian terdiri atas 34 mahasiswa pada kelompok eksperimen dan 33 mahasiswa pada kelompok kontrol. Mahasiswa partisipan adalah mahasiswa pendidikan fisika semester ke empat, di salah satu perguruan tinggi negeri di Kalimantan Timur. Instrumen penelitian terdiri dari butir tes pilihan ganda bermuatan keterampilan berpikir kreatif. Data dianalisis dengan uji perbedaan dua rerata. Rerata skor gain yang dinormalisasi  $\langle g \rangle$  pada aspek keterampilan berpikir kreatif kelompok eksperimen adalah sebesar 0,60 dan kelompok kontrol sebesar 0,31. Hal ini mengindikasikan bahwa keterampilan berpikir kreatif mahasiswa calon guru fisika meningkatkan cukup signifikan setelah mereka mengalami pembelajaran termodinamika dengan multimedia interaktif. Dengan demikian dapat disimpulkan bahwa penggunaan multimedia interaktif meningkatkan keterampilan berpikir kreatif mahasiswa calon guru fisika.

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**Keywords:** interactive multimedia; thermodynamics; creative thinking skills; physics prospective teachers

### INTRODUCTION

In an ever-changing societal situation and increasingly severe challenges, an educator should look far ahead and think about what will be facing by learners in a future. In a histo-

rical perspective, the 21st century learning developed in the United States in 2007 supported by other developed countries including Australia which was pioneered by The Partnership for 21st Century Skill has important purposes. They resulted formulation that students should be facilitated in order to have skills of communication, creative thinking, collaboration, critical thinking, and problem solving (Pacific Policy

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Research Center [PPRC], 2010). The knowledge and ability obtained can be made provision of life in a community that has both local and global character and can be accounted personally and socially. The ability to think creatively will effectively facilitate students in solving the challenges associated with events in everyday life. Therefore, the ability of creative thinking is very important to be developed and owned by students in the learning process and after the learning process.

Thermodynamics has a dynamic character and requires creativity in solving the problem. This material can be used as a vehicle for developing creative thinking skills. However, the obstacles faced are the content of material given by textbooks still tend to be mathematical, many formulas, many contain abstract concepts, based on principles, and state the processes and cycles that all this less support the development of creative thinking. These have been investigated and reported by Lewis, et al. (1993) which state that students are not able to integrate thermodynamic concepts in complex phenomena. Huang and Gramoll (2004) find out from the results of their research that students have difficulty in visualizing abstract concepts. In Carnot cycle material, students still have difficulty how to apply p-V diagram to solve the problem (Kulkarni & Tambade, 2013). Christensen, et al. (2009) found that students experienced misinterpretation in understanding the laws of the ideal gas. The constraints found by the researches turn out to affect the ability of students in understanding the material, causing frustration in building mental models, tend to be boring, so that adversely affect their learning outcomes. Based on these findings, it is deemed necessary to provide visualization of abstract concepts that students are difficult to understand in the form of animations, simulations, and virtual labs. However, dynamic visualization can not be obtained through printed books, so it takes computer technology to develop dynamic visualizations that can be used in the learning process. The resulting visualization can be interactive multimedia courseware or learning software. Through animation, simulation, and virtual laboratory students will be facilitated to be able to build knowledge and develop the ability to think creatively.

Several studies related to the use of interactive multimedia in learning have been able to help and facilitate the improvement of concepts mastery and students' creative thinking skills. The integration of computer animation

in effective learning helps students to improve their understanding in various concepts of physics (Kohnle, et al., 2012; Dega, et al., 2013). Interactive multimedia can visualize and simplify abstract thermodynamic concepts such as enthalpy and entropy. This is expressed by Liu (2006) which states that abstract concepts such as the gas laws are more easily understood by using multimedia. Junglas (2006) suggests that the use of interactive simulations will improve students' mental models. McKagan, et al. (2008) stated that interactive software helps students to understand abstract concepts on quantum mechanical. Doyan and Sukmantara (2014) reported that learning with an effective web intranet enhances the mastery of concepts such as work, energy, and power. The research results of Siswanto, et al. (2016) also showed that the use of E-Lab effectively enhances the understanding of physics concepts. It can be concluded that to be able to enhance the students' ability to integrate thermodynamic concepts in complex phenomena and enhance understanding, the use of interactive multimedia using simulations, movies, diagrams, graphics, animations, and sounds plays a vital role to help visualize and simplify abstract concepts that students can not comprehend. In addition, the power of interactive multimedia is to give students the opportunity to study the material at any time, respond quickly, accustom to creative thinking, and encourage students' curiosity to conduct investigations. It is corroborated by Podolefsky, et al. (2010) who stated that learning by using simulations can develop students' ability to investigate, establish relationships between representation, and analogy to understand scientific ideas.

Recently, experts have been researching, designing, and developing lessons by using information and communication technology. Results of overview Mulop, et al. (2012) from 1993 to 2009 in several journals related to the utilization of information and communication technology in thermodynamic lectures states that the tendency of research in thermodynamic learning can be grouped into three groups namely; (1) the use of multimedia to assist students in problem solving (Baher, 1998; Ngo & Lai, 2003; Liu, 2009); (2) use of simulation and multimedia programs to improve student interactivity (Baher, 1998; Kumpaty, 2002; Ngo, 2003; Anderson, Taraban, & Sharma, 2005; Hassan & Mat, 2005; Junglas, 2006; Bullen & Russell, 2007; Chaturvedi, Abdel-Salam, & Kasinadhuni, 2007; Weston, 2008; Liu,

2009); (3) the use of interactive multimedia and simulations to enhance the ability of reflection and application of scientific ideas (Ngo, 2003; Jonnassen, et al., 2009). Based on these results, no one has developed and implemented a comprehensive interactive multimedia that includes animation, simulation, virtual labs, and interactive exercises aimed at improving the creative thinking skills of prospective teachers in thermodynamic learning. Therefore, it is necessary to implement interactive multimedia thermodynamics that other researchers have developed to enhance creative thinking skills with different nuances or designs with existing interactive multimedia as in Figure 1.

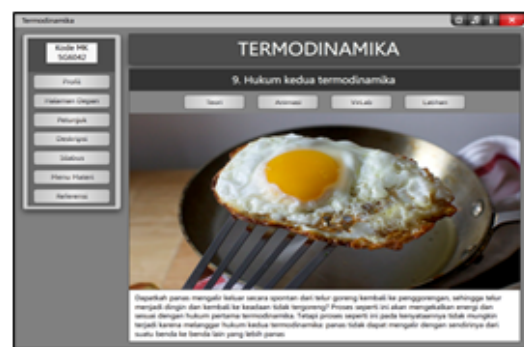
Interactive thermodynamic multimedia is structured using four main components: theory, animation, virtual labs, and practice. The purpose of each component is; (1) theory, contains important concepts and is a supplementary textbook owned by students and in this section there is an animated link related to the concept learned; (2) animation, used to help students understand a process and thermodynamic cycle, diagram form each process or cycle, and assist students in developing creative thinking skills, and each animation is equipped with a brief explanation; (3) virtual labs, used as a component to perform student's main activities

in developing creative thinking skills. Virtual experiments along with student-oriented student inquiry sheets are designed to allow students to experiment virtually, to formulate hypotheses, collect, analyze data, and draw conclusions; (4) exercises, used by students at the end of learning after learning thermodynamic concepts and conducting experimental activities in order to test students' understanding. This exercise is also designed by giving feedback to users to check their answers.

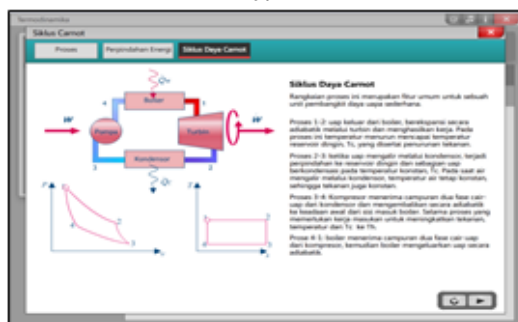
The thermodynamic materials which are the focus of this study are the basic concepts of thermodynamics, energy and the first law of thermodynamics, the properties of pure substances, the ideal gas, the second law of thermodynamics, as well as the Carnot cycle. This developed interactive multimedia not only serves as a development of mastery of thermodynamic concepts, but also can develop indicators of creative thinking skills. These indicators include fluency, flexibility, elaboration, and originality. Therefore, the purpose of applying interactive multimedia-based Thermodynamic learning in this research is to improve the creative thinking skill of physics teacher candidate. Stages of interactive multimedia-based Thermodynamics learning can be described in Table 1.



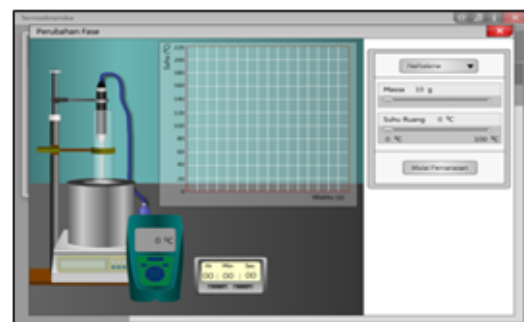
(a)



(b)



(c)



(d)

**Figure 1.** Example of Interactive Multimedia Interface Thermodynamics: (a) front page; (b) material; (c) animation; (d) virtual laboratory.

**Table 1.** Learning Stage of Interactive Thermodynamics Multimedia (ITMM)

Stages	Students Activities	AbilitiesnTrained
Orientation	Recognize thermodynamic materials and concepts, objectives and problems to be solved. Studying thermodynamic concepts through ITMM to gain knowledge as a basis for problem solving.	Understanding Thermodynamics concepts
Exploration	Students discuss in groups (3-4 persons) to infer the intent and design their problem solving through virtual experiments or steps to be performed. Students conduct virtual experiments on a virtual lab menu: - Presenting divergent questions - Formulate hypotheses - Designing virtual experiments - Conduct virtual experiment - Collect and analyze data - Make a conclusion	Fluency Flexibility Originality Elaboration Flexibility
Presentation	Communicate the results of the investigation through group presentations	Fluency
Evaluation	Doing the exercises through ITMM, Writing a summary, Record individual and group assignments.	Elaboration

## METHOD

The method used in this research is quasi experiment with control group pretest-posttest design (Fraenkel, 2007). In this design there are two groups, namely experimental group ( $n = 34$ ) and control group ( $n = 33$ ). The experimental group received learning using interactive multimedia thermodynamics and the control group gained traditional learning. The two groups performed pretest and posttest creative thinking skills in the form of multiple choices consisting of 40 questions. The result of qualitative question validity analysis by three experts shows that the question of creative thinking in the thermodynamic context is valid to be used and the result of quantitative validity (product moment) shows a significant result (valid). The reliability of the question using the Cronbach alpha value criterion is 0.79. These results show that the creative thinking skills developed have high internal consistency. The data of the two groups were analyzed using the mean difference test (T test or Mann-Whitney) and normalized gain scores  $\langle g \rangle$ . Normalized gain scores by the formula (Hake, 1998):

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

where,  $S_f$  = posttest scores,  $S_i$  = pretest scores by categories yaitu: low ( $\langle g \rangle < 0,3$ ), moderate ( $0,3 \leq \langle g \rangle \leq 0,7$ ), and high ( $\langle g \rangle \geq 0,7$ ).

Level of significance of two-averaging test used effect size calculation ( $d$ ). According to Morgen, et al. (2004) results of significant differences do not provide information about the quality of the differences between the two data groups. Therefore, Cohen (Morgen, et al., 2004) recommends a significant difference with five categories: very small ( $d < 0.2$ ), small ( $0.2 \leq d \leq 0.5$ ), moderate ( $0.5 < d \leq 0.8$ ), high ( $0.8 \leq d < 1.0$ ), and very high ( $d \geq 1.0$ ). By the formula:

$$d = (M_E - M_C) / \sqrt{(SD_E^2 + SD_C^2) / 2} \quad (2)$$

where,  $M_E$  = average scores of experimental group,  $M_C$  = average scores of control group,  $SD_E$  = deviation standard of experimental group,  $SD_C$  = deviation standard of control group.

## RESULTS AND DISCUSSION

The indicator of creative thinking skill developed in this research consists of four indicators namely fluency, flexibility, elaboration, and originality. To determine the achievement of interactive multimedia-based thermodynamic learning related to the creative thinking

**Table 2.** Pretest, posttest, and normalized gain scores <g> of each indicator of creative thinking skills in the experimental and control groups

Creative Thinking Indicators	Experimental Group (n=34)		<g> (%)	Control Group (n=33)		<g> (%)
	pretest	posttest		Pretest	posttest	
Fluency	34.22	71.12	56	36.36	59.05	36
Flexibility	44.22	85.09	72	40.96	58.33	29
Elaboration	34.33	76.52	60	35.37	53.76	28
Originality	36.47	70.27	49	35.45	54.85	31

ability of prospective physics teachers, normalized gain scores <g> were analyzed in the experimental and control groups. The average pretest, posttest, and normalized gain scores <g> of each indicator of creative thinking in the experimental and control groups is presented in Table 2.

Normalized gain scores <g> of the fluency indicators in the experimental and control groups showed a moderate increase (Table 2). This suggests that interactive multimedia-based thermodynamic learning can improve the ability of creative thinking in fluency indicators. The flexibility indicator score shows a moderate increase in the experimental group and a low increase in the control group. This shows that interactive multimedia-based thermodynamic learning can improve the ability of creative thinking in flexibility indicator. The elaboration indicator score was a moderate increase in the experimental group and the low increase in the control group. This shows that interactive multimedia-based thermodynamic learning can improve the ability of creative thinking in elaboration indicator. Normalized gain scores <g> indicator of originality in the experimental group and control group shows a moderate increase in the experimental group and control group. The improvement of the four indicators of creative thinking can not be separated from the learning process with ITMM that has been done experimental group. By using the learning of ITMM the lecturer's dominance is reduced, but his role as a facilitator persists.

Students appear to be increasing fluency ability when students trigger many ideas or hypotheses to solve problems with the help of ITMM. In addition, through the presentation of experimental results of trained students foster fluency skills. The flexibility capability is grown at least in two ways through ITMM and when asking divergent questions to solve problems collaboratively. For example, in thermocouple

experiments, students ask the question such as: How the sensitivity of various metal wires as temperature sensors? How big is the seebeck coefficient generated by the junction between the wires for different types of thermocouples ? Elaboration skills are grown when students conduct experiments, collect and analyze data. For example, it presents data in the form of tables, graphs, and mathematical equations. Originality skills are grown as students plan experiments and create unusual combinations. For example, setting up and assembling tools virtually. The results of the interactive thermodynamics multimedia-based learning and the indicators of creative thinking abilities are presented in Table 3.

Table 3 shows that the improvement of creative thinking ability in each indicator between the experimental group and the control group are significantly different. Normalized gain scores <g> of experimental group and control group are in moderate category. The results of difference test of two averages at  $\alpha = 0.05$  shows a significant difference of improvement of creative thinking skills between experiment group and control group. Effect size (d) of each indicator of creative thinking skills are in very high category. This shows that the learning of thermodynamics using interactive multimedia is quite effective in improving the creative thinking skills of prospective physics teacher rather than learning without interactive multimedia thermodynamics in regular learning.

The result of data analysis showed that the normalized gain score <g> on the flexibility indicator in the experimental group was higher than the control group, whereas the lowest normalized gain score <g> is in the originality indicator both in the experimental group and the control group. Overall improvement in creative thinking skills has not been satisfactory. Creating interactive multimedia that can lead to the

**Table 3.** Normalized gain scores <g> each indicator of creative thinking skills in the experimental and control groups

Creative Thinking Indicators	Normality Test		Test of Average of Differences (Z and t)		Significances	d
	Experimental	Control				
Fluency	Not Normal (Sig. 0.012)	Normal (Sig. 0.200)	Z = -4.073	Sig. 0.000	Significantly different	1.05
Flexibility	Not Normal (Sig. 0.000)	Not Normal (Sig. 0.000)	Z = -4.775	Sig. 0.000	Significantly different	1.40
Elaboration	Normal (Sig. 0.170)	Normal (Sig. 0.200)	t = 10.148	Sig. 0.000	Significantly different	0.95
Originality	Normal (Sig. 0.200)	Normal (Sig. 0.200)	t = 4.539	Sig. 0.000	Significantly different	1.05

Normality Test = Kolmogorov-Smirnov Test (normal, sig.>0.05),  $p < 0,05$ .

improvement of creative thinking skills of prospective physics teachers is not an easy thing. Therefore, a more rigorous and comprehensive analysis of the appropriateness between each indicator of the creative thinking skill developed with the characteristics of the material, animation, simulation, and the virtual laboratory used, the learning activities performed, and the instruments used for further improvement the creative thinking ability of physics teacher candidate students should be done.

All the indicators of creative thinking skills in the experimental and control groups experienced an increase in moderate and significantly different categories (Table 3). This shows that the learning of thermodynamics using interactive multimedia is quite effective in improving the creative thinking ability of prospective physics teacher compared with learning without interactive multimedia. These results reinforce some previous research results related to the use of information and communication technology in learning. According to Wheeler, et al. (2002), the use of ICT in learning can improve students' creative thinking ability. Similar disclosed Laisema and Wannapiroon (2014) that the use of information technology in learning is effectively support the development of creative thinking skills of the students.

Faizin (2009) has stated that interactive multimedia learning model can be used in physics teaching and learning as: (1) Virtual laboratory through modeling and presentation of phenomena and processes. (2) An expressive learning space for students to demonstrate their ideas, predict, lower the laws of physics and solve problems. The simulation of concepts and phenomena of physics through interactive multimedia simulation will be effective in teaching the students because: (1) Supporting

a strong learning space in studying the physical symptoms, (2) Easy to use and flexible, and (3) Easily accessible in the computer environment. Ivers, et al. (2002) revealed that multimedia can encourage students to learn in groups, convey their knowledge in different ways, solve problems, revise their work, and build knowledge. Computer simulations can encourage students to investigate, ask questions, make predictions, hypothesize (Tawil, 2011), observe, and interpret results (Kulkarni & Tambade, 2013), developing high-level thinking skills of students (Reshaw & Taylor, 2000). Furthermore, computer simulations can facilitate students in formulating and testing hypotheses and as a vehicle to match their ideas to what they observe in simulations (Zacharia, 2003).

The high normalized gain score <g> in the experimental group was not separated from the learning activities they experienced. In the experimental group, students have the opportunity to directly teach themselves thoroughly, construct their understanding, and train their creative thinking skills. Each material is equipped with animation, simulation, and virtual labs. Through the virtual laboratory activities students are trained to develop their creative thinking skills, such as fluency indicators, where students always think of various answers or solutions to the hypotheses that have been formulated. The flexibility indicator, reflected in the student's ability to build a systematic relationship and inductive reasoning to make conclusions. The elaboration indicators showed by the students' ability to add or itemize the object becomes more interesting through measuring, collecting, managing, and analyzing experimental data. Indicator of originality, observed from the students skills in designing experimental activities to be performed. In the



control group the students receive only a single amount of informations; they lack the opportunity to develop their creative thinking skills.

## CONCLUSION

Based on the results of the research, it can be concluded that (1) interactive multimedia thermodynamics which developed in Thermodynamics learning can improve the creative thinking skill of prospective physics teacher; (2) the highest improvement of creative thinking skills occurs in the flexibility indicator and the lowest in the indicators of originality; (3) learning by using interactive multimedia thermodynamics is quite effective in improving the creative thinking skills of prospective physics teacher rather than regular learning, without interactive multimedia thermodynamics.

## REFERENCES

- Anderson, E. E., Taraban, R., & Sharma, M. P. (2005). Implementing and assessing computer-based active learning materials in introductory thermodynamics. *International Journal of Engineering Education*, 21(6), 1168-1176.
- Baher, J. (1998). How articulate virtual labs can help in thermodynamics education: a multiple case Study. *28<sup>th</sup> Annual FIE Conference*, 2, pp. 663-668.
- Bullen, P., & Russell, M. (2007). A blended learning approach to teaching first year engineering degree students. *International Conference on Engineering Education-ICEE 2007*. Coimbra, Portugal.
- Chaturvedi, S., Abdel-Salam, T., & Kasinadhuni, O. (2007). Virtual Assembly - A web-based student learning tool for thermodynamics concepts related to multistaging in compressors and turbines. *International Conference on Engineering Education-ICEE 2007*. Coimbra, Portugal.
- Christensen, W., Meltzer, D., & Ogilvie, C. (2009). Students' ideas regarding entropy and the second law of thermodynamics in an introductory physics course. *American Journal of Physics*, 77(10), 907-917.
- Dega, B. G., Kriek, J., & Mogese, T. F. (2013). Conceptual change in electricity and magnetism using simulation: A comparison of cognitive perturbation and cognitive conflict. *Journal of Research in Science Teaching*, 50(6), 677-698.
- Doan, A., & Sukmantara, I K, Y. (2014). Pengembangan Web Intranet Fisika untuk Meningkatkan Penguasaan Konsep dan Kemampuan pemecahan Masalah Siswa SMK. *Jurnal Pendidikan Fisika Indonesia*, 10(2), 117-127.
- Faizin, M. N. (2009). Penggunaan model pembelajaran multimedia interaktif pada konsep listrik dinamis untuk meningkatkan penguasaan konsep dan memperbaiki sikap belajar siswa. *Research Report*. Kudus : SMPN 2 Kudus.
- Forbus, K. D., Whalley, P. B., Everett, J. O., Ureel, L., Brokowski, M., Baher, J., & Kuehne S. E. (1999). CyclePad: An articulate virtual laboratory for engineering thermodynamics. *Artificial Intelligence*, 114, 297-347.
- Fraenkel, J. R., & Wallen, N. E. (2007). *How to Design and Evaluate Research in Education* (2<sup>nd</sup> ed.). New York: McGraw-Hill Book Co.
- Hake, R. (1998). Interactive-engagement vs traditional methods: a six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66, 64-74.
- Hassan, O., & Mat, R. (2005). A Comparative Study of Two Different Approaches in Teaching Thermodynamics. *Regional Conference on Engineering Education*. Johor.
- Huang, M. & Gramoll, K. (2004). Online Interactive Multimedia for Engineering Thermodynamics. *Proceeding of ASEE Annual Conference and Exposition*, pp. 10661-10671.
- Ivers, Karen S. & Barron, A. E. (2002). *Multimedia Projects in Education: Designing, Producing, and Assessing*. America: United States of America.
- Jonassen, D., Mates, T., & McAleese, R. (1993). A manifesto for a constructivist approach to uses of technology in higher education: in designing environments for constructivist learning. Berlin: *Springer-Verlag*, 231-247.
- Junglas, P. (2006). Simulation Programs for Teaching Thermodynamics. *Global Journal of Engineering Education*, 10(2), 175-180.
- Kelly, G. (2002). *A powerful virtual learning environment*. Teaching and Educational Development Institute, University of Queensland, Australia.
- Kohnle, A., Cassettari, D., Edwards, T. J., Ferguson, C., Gillies, A. D., Hooley, C. A., & Sicclair, B. D. (2012). A new Multimedia resource for teaching quantum mechanics concepts. *American Journal of Physics*, 80(2), 148-153.
- Kulkarni, V. D., & Tambade, P. S. (2013). Enhancing the Learning of Thermodynamics using Computer Assisted Instructions at Undergraduate Level. *Eurasian Journal of Physics & Chemistry Education*, 5(1), 2-10.
- Kumpaty, S. K. (2002). Learning enhancement in thermodynamics classroom via use of TESS-TM software in design projects and laboratory. *American Society for Engineering Education Annual Conference & Exposition*.
- Laisema, S., & Wannapiroon, P. (2014). Design of Collaborative Learning with Creative Problem-Solving Process Learning Activities in a Ubiquitous Learning Environment to Develop

- Creative Thinking Skills. *Procedia-Social and Behavioral Sciences*, 116, 3921-3926.
- Lewis, E. L., Stern, J. L., & Linn, M. C. (1993). The Effect of Computer Simulation on Introductory Thermodynamics Understanding. *Education Technology Journal*, 33, 45-58.
- Liu, X. (2006). Effects of Combined Hands-on Laboratory and Computer Modeling on Student Learning of Gas Laws: A quasi-experimental study. *Journal of Science Education and Technology*, 15, 89-100.
- Liu, Y. (2009). *Development of instructional courseware in thermodynamics education*. Wiley Periodicals, Inc. Comput Appl Eng Educ.
- McKagan, S.B; Perkins, M., Dubson, C., Malley, S., Reid, R., LeMaster., & Wiemna, C.E. (2008). Developing and Researching PhET Simulation for Teaching Quantum Mechanics. *Physics Education Technology*. <http://www.colorado.edu/iSTEM/pdfs/QMsims.pdf>.
- Morgen, G. A., Leech, N. L., Gloeckner, G. W., and Barrett, K. C. (2004). *SPSS for Introductory Statistics: Use and interpretation* (2<sup>nd</sup> ed.). New Jersey: Lawrence Erlbaum Associates Inc.
- Mulop, N., Yusop, K., & Tazir, Z. (2012). A Review on Teaching and Learning of Thermodynamics. *Procedia-Social and Behavioral Sciences*, 56, 703-712.
- Ngo, C. C., & Lai, F. C. (2003). An online thermodynamics courseware, *Computer Applications in Engineering Education*, 11(2), 75-82.
- Pacific Policy Research Center [PPRC]. (2010). *21<sup>st</sup> Century Skills for Students and Teachers*. Honolulu: Kamehameha Schools, Research & Evaluation Division.
- Podolefsky, N. S., Perkins, K. K., & Adams, W. K. (2010). Factor Promoting Engaged Exploration with Computer Simulation. *Physics Education Research*, 6(2), 020117-1-020117-11.
- Reshaw, C. E., & Taylor, H. A. (2000). The educational effectiveness of computer based instruction. *Computer and Geosciences*, 26(6), 677-682.
- Siswanto, J., Saefan, J., Suparmi, & Cari. (2016). Keefektifan E-Lab untuk Meningkatkan Keterampilan Generik Sains dan Pemahaman Konsep Fisika. *Jurnal Pendidikan Fisika Indonesia*, 12(1), 33-40.
- Tawil, M. (2011). *Pengembangan Pembelajaran Berbasis Simulasi Komputer pada Perkuliahan Gelombang dan Optika untuk Meningkatkan Keterampilan Berpikir Kreatif Calon Guru Fisika*. Disertasi SPS UPI: Tidak Dipublikasikan.
- Weston, A. J. Interactive thermodynamic Cycles using HTML and JavaScript. Retrieved December 2008, from file:///N:/resource/tommy/Summary.html
- Wheeler, Waite, & Bromfield. (2002). Promoting Creative Thinking Through the use of ICT. *Journal of Computer Assisted Learning*, 18, 367-378.
- Zacharia, Z. (2003). Beliefs, attitudes, and intentions of science teachers regarding the educational use of computer simulations and inquiry-based experiments in physics. *Journal of Research in Science Teaching*, 40, 792-823.

## DETERMINANTS FACTORS ANALYSIS OF INDONESIAN STUDENTS' PHYSICS ACHIEVEMENT IN TIMSS 2011

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### ABSTRACT

This study aimed to find the structure of the theoretical model that can illustrate the achievements of Indonesian students in the field of physics. This study also examines the variables that directly or indirectly influence the physics achievement of Indonesian students. The data in this study are data of TIMSS 2011 on physics test with population involved were 4572 Indonesian students grade 8. This research used path analysis from LISREL 8.30. The physics achievement model of Indonesian students based on TIMSS 2011 results are as follows: (1) physics achievement is directly influenced by self-confidence, interest in learning, and students' attitudes toward the importance of physics; (2) physics achievement indirectly influenced by students' involvement in physics learning indicated from their interest and confidence in physics learning; (3) attitudes toward the importance of physics have an indirectly positive impact on physics achievement. Students' self-confidence in physics learning has a stronger direct influence on their achievements than their interest in physics.

### ABSTRAK

Penelitian ini bertujuan untuk menemukan struktur model teoretis yang dapat menggambarkan prestasi siswa Indonesia bidang fisika. Penelitian ini juga meneliti variabel-variabel yang berpengaruh secara langsung maupun tidak langsung terhadap prestasi fisika siswa Indonesia. Data penelitian ini berasal dari data TIMSS 2011 pada mata uji fisika dengan populasi yang terlibat sebanyak 4572 siswa Indonesia Kelas 8. Penelitian ini menggunakan path analysis dengan bantuan LISREL 8.30. Model prestasi fisika siswa Indonesia berdasarkan hasil TIMSS 2011 adalah sebagai berikut: (1) Prestasi fisika dipengaruhi secara langsung oleh percaya diri, minat belajar, dan sikap siswa terhadap pentingnya fisika, (2) Prestasi fisika dipengaruhi secara tidak langsung oleh keterlibatan siswa dalam pelajaran fisika melalui minat dan percaya diri dalam belajar fisika. (3) Sikap terhadap pentingnya fisika berpengaruh tidak langsung secara positif terhadap prestasi fisika. Percaya diri siswa dalam belajar fisika mempunyai pengaruh langsung yang lebih kuat terhadap prestasi mereka dibandingkan minat mereka terhadap fisika.

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**Keywords:** determination; factors; Indonesian; physics achievement; TIMSS 2011

### INTRODUCTION

High achievements in the fields of science and mathematics are important for students preparing for college, adjusting in the workplace, or in daily life (Mullis et al., 2012). A trend in International Mathematics and Science Study (TIMSS) produces contextual information of each country with regard to student achievement analysis and its comparisons with the achievements of other countries. This in-

ternational comparative study includes various factors such as: schools resources, family characteristics, and students' attitudes, all of which can affect students' achievement. Surveys conducted through TIMSS in the field of science include 8 aspects, namely: (1) International Student Achievement in Science (7 variables); (2) Performance at the TIMSS 2011 International Benchmarks (17 variables); (3) International Student Achievement in the TIMSS Science Content and Cognitive Domains (6 variables); (4) Home Environment Support for Science Achievement (4 variables); (5) School

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Resources for Teaching Science (8 variables); (6) School Climate (6 variables); (7) Teacher Preparation (8 variables); and (8) Classroom Instruction (18 variables). Classroom Instruction is subdivided into 4 sub-variables; they are (1) Students' Attitudes toward Science; (2) Instructional Time; (3) Students Ready to Learn; (4) Classroom Resources and Activities for Teaching Science. Students' Attitudes toward Science consists of 3 variables, namely (1) Students Interest in Learning Science; (2) Students Value Science; (3) Students Confidence in Science (Martin, et al., 2012).

Indonesia has been involved four times in the TIMSS research for 8th grade in 1999, 2003, 2007, and 2011. In 2015 Indonesia only participated in the survey for grade 4. Based on data from four times following the TIMSS research, the average score of Indonesian students for the science category was 405 and in the category of Low Performance Country. This score is far below the average score of 500. The average score of Indonesian students for Science in the 2011 TIMSS survey was 406 or at rank of 40 of 42 countries. Specifically for physics test, the Indonesian students get score of 397 or at rank 40 of 42 countries. The first rank was achieved by Singaporean students with score of 602 and Malaysian students at the 32nd place with a score of 435 (Martin, et al., 2012). Based on these data, the score of physics material of Indonesian students was lower than the science score in general. There is interesting information related to the TIMSS Physics test of Indonesian students when they are given problems related to the ability to know what happens when molecules are cooled, only 35% of students can answer correctly. Similarly, when Indonesian students were given problems related to the influence of gravity on someone who did parachuting, none of Indonesian students managed to answer (Martin et al., 2012). This is a concern and requires serious efforts to fix those problems and improve its quality. Overall, the achievement of the Indonesian students' scores of sciences in Low-Interest (54%), Intermediate International Benchmarking (19%), High International Benchmarking (3%), and in the Advanced International Benchmarking category of 0% (Martin, et al., 2012).

There are a number of aspects surveyed in TIMSS. This fact provides an opportunity for further research relating to factors that significantly influence student achievement in a country, so that appropriate policy can be taken

to improve the quality of education. Potential factors affect student achievement in some countries so that it can be mapped determination of variation between countries on student achievement. Similarly, on the achievement of Physics in Indonesian students, based on the acquisition of TIMSS it is necessary to find the root cause of the low achievement of Indonesian students. There needs to be a more comprehensive study related to the factors that are very dominant influence student's physics achievement, especially in Indonesia. This is homework for stakeholders in formulating policies for improvement in all aspects of learning. Therefore, the first step that can be done is to develop a model of physics achievement of Indonesian students based on the variables involved and measured in TIMSS.

Physics learning achievement is the main variable that often become the focus and the main indicator of teacher and student success in Physics learning. There are several studies involving many psychological variables that can be used as predictors of physics learning achievement. Ariyo and Ibeagha (2008) conducted research on physics learning in senior high school involving 22 schools, 22 principals, 22 physics teachers and 330 students with path analysis techniques. The research results show that there are 8 variables that significantly influence student's physics achievement in Nigeria: (1) physics general aptitude, (2) students' gender, (3) students' attitude, (4) school type, (5) physics practical skills, (6) physics teacher qualification, (7) problem solving skills and (8) principal's area of specialization. Vahedi and Yari (2014) studied the influence of cognitive and emotional factors on physics learning achievement in high school students in Tabriz city, Turkey with linear regression and correlation analysis techniques. The results showed that: (1) there was a significant and positive relationship between epistemological belief, attitude toward science, prior knowledge of chemistry and mathematics with physics achievement, (2) there was a significant and negative relationship between physics anxiety and physics achievement.

A comprehensive study was conducted by Mujtaba and Reiss (2014) involving 5034 10th grade students (15 ages) from 137 schools in the UK in the 2008/2009 academic year related to Physics learning. This study uses factor analysis techniques and involves several variables including: motivation, intrinsic value of physics, home support for achievement

in physics, emotional response to physics learning, perceptions of physics learning, physics self-concept and advice-pressure to study physics. The results of the study found that: (1) extrinsic motivation is the most important factor of factors involving students' involvement, (2) advice-pressure to study physics and teachers is a key factor in order for students to learn physics continuously. Mujtaba and Reiss research (2014) is in line with previous research by Perez, Costa & Corbi (2012) which explains that the two main variables affecting learning achievement in general are Aptitude (general intelligence) and self concept (motivation) in addition to goal and effort orientation Self-involvement). The study involved 341 students and 7 variables using structural equation modeling (SEM) analysis techniques. The results of the research show: (1) General intelligence is a very dominant factor affecting learning achievement, (2) Student's goal orientation and academic self-concept very strong influence to effort (effort) or self-involvement in learning, (3) Student motivation and effort Students influence the selection of appropriate learning strategies.

Walberg (2004) developed the theory based on more than 100 research results about factors that affect the achievement of learning. The theory explains that factors influencing learning achievement are divided into three parts: (1) Variabell Student aptitude which includes previous ability or achievement, motivation or self-concept and mental development based on age, (2) instructional variables that include time And quality of learning and (3) environmental variables that include involving home, classroom peer and exposure to mass media. The first variable deals with the personal and background characteristics, the second variable relates to the learning aspect and the third variable relates to the social psychology of the home, class and peer atmosphere. With respect to Student aptitude variables, initial abilities were measured by standardized tests, motivation using survey and age-based mental development level (Paik, 2004; Reynolds & Walberg, 1992)

Suter (2000), in a study comparing mathematics and science achievement of students at international level using TIMSS data concluded that the differences in learning achievement among countries are determined more by curricular and teaching variables. Further, Suter (2000) cites the results of James Colamen's (1960) study which concluded that more achievements are determined by the fa-

mily background than the school background. Similarly, Suter (2000) cites the conclusions of Gustafsson & Undheim (1996) that the differences in student's achievement among countries are more due to curricular and teaching variables than intelligence. Hayneman (1997: 29) found the opposite data that student personal variables are more determinants of achievement, especially motivation. Wilkins, Zembylas and Travers (2002) conducted a study with 1995 TIMSS data from 16 countries and gave results that belief in student self-efficacy was consistent predictor of mathematics and science achievement. Shen and Tam (2008) used TIMSS data (1995, 1999, and 2003) to examine the relationship between self-concept and achievement in grade 8 students. The results show that in all countries there is a positive and significant relationship between self-concept and achievement. Fathi, et al. (2013) conducted a study of TIMSS results in 2007 involving 3981 students with TIMSS data in 2007 and 4 variables of each science achievement, science self concept, father's education and attitude to science. The research used structural equation modeling (SEM) analysis and found that: (1) science self-concept and attitude toward science have positive impact on achievement; and (2) father's education has no significant impact on attitude to science. Topcu, et al. (2016) conducted a comparative study of factors affecting science learning achievement in Turkey and Korea based on TIMSS results in 2011. The study resulted in information that: (1) aptitude, learning and environmental aspects influenced the achievement of science; (2) in both countries, science self-efficacy and parental education levels have a significant impact on sians and mathematics achievement; and (3) School environment variables such as bullying and student sense of belonging at school have different impacts on both countries.

The Indonesian Education Assessment Center (2010) conducted a study of the results of TIMSS for science in 2007 on Indonesian students. The results of this study conclude as follows: (1) self-efficacy directly affect the achievement of science except for earth science; (2) attitudes toward the learning process affect self efficacy against the same subjects but not all of them continue to impact the self-efficacy of science achievement except for earth science; (3) students' perceptions of the importance and absence of science each affect the attitudes toward the lesson; (4) teaching methods can influence attitudes even if they occur only in

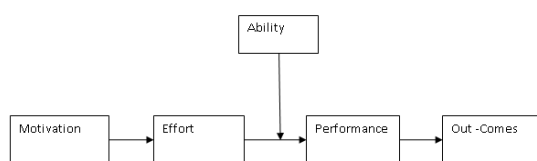
Biology and Chemistry (Indonesian Education Assessment Center, 2010: 32).

From the various studies of TIMSS both conducted abroad and in Indonesia there are several variables that consistently become predictors or consistently affect the achievement of learning, especially science and mathematics, although not all subjects have the same pattern. Of the various studies show that the achievements generated by students is not the result of a factor, but the result of various factors that are related to each other. Factors that are considered influential on physics learning achievement can be distinguished based on data obtained from the level of students from student questionnaires and school level from teacher and principal's questionnaire data.

At the internal level of students, there are several psychological theories that influence learning achievement. First, the theory was built by Heider (1958), who used the approach of attribution theory with a mathematical formula approach that connects performance factor (P), motivation (M) and ability (A) as in the following equation.

$P = MXA$  (Indonesian Education Assessment Center, 2010).

As seen in the formula that the achievement of learning or performance is the result of interaction between motivation and ability. Thus students who have high motivation but have low ability will result in low performance, as well as those that occur in students who have high ability but have low motivation. Porter and Lawler (1968) developed different performance theories. The idea can be seen in Figure 1.



**Figure 1.** The relationship between motivation and learning outcomes by Porter & Lawler (Taylor, 2007).

Porter & Lawler's theory (Taylor, 2007) as described in Figure 1 shows that motivation gives influence to the effort to be performed. Conversely, efforts affect the performance, and ultimately the performance impact on learning outcome. Ability becomes a moderator of effort and performance relationships. A student may have high motivation and effort but with low ability leads to poor performance. Conversely

some students have less effort but have a good enough performance because it has high ability.

This research is a preliminary study related to student physics achievement model of Indonesian students based on TIMSS data. In this regard, it is necessary to limit the variables involved so that the theoretical model can get support from the existing data. This study is limited to five variables that are at student level and related to physics learning are: (1) students' Interest in and liking of learning physics; (2) students' attitudes about the importance of the physics; (3) students' self confidence in their ability to learn physics; (4) students' engaged in physics lesson; and (5) achievement in physics.

Therefore, this study aims (1) to find theoretical model structure that can illustrate the achievements of Indonesian students in the field of physics; (2) to find the variables that directly or indirectly affect the Indonesian student achievement in physics; and (3) to find the dominant variable influencing the Indonesian student achievement in physics.

## METHOD

Data analyzed in this study is data from TIMSS 2011. The population is the students in grade 8 of each participating countries. Since following TIMSS's first research up to 2011, Indonesia has included for 8th graders. But by 2015, Indonesia is only included for grade 4. The sampling procedure for TIMSS 2011 has been determined by TIMSS & PIRLS International Study Center in cooperation with the Statistics Canada and the IEA Data Processing and Research Center. The research coordinator of each participating country along with the sampling expert from TIMSS selects the sample using the planned procedure. The sampling procedure used is a two-stage cluster design. On the first stage, the school sample was chosen proportionally to the size of the region whereas on the second stage, the class chose randomly from the designated school. All tests and questionnaires were given to all students in each class. This procedure is used to derive class-based conclusions as well as curriculum and learning experiences (Joncas & Foy, 2012). The 8th grade Indonesian students who were involved in the 2011 TIMSS study were 5795 from 153 state and madrasah schools (Joncas, 2011). There were 1223 students who were incomplete in responding to all the test

items or questionnaires so that they could not be used as sample members in the study, so that this study uses only 4572 sample sizes. Student response data is accessed by researchers from the Center for Educational Assessment, Research and Development Agency, Ministry of Education and Culture of the Republic of Indonesia.

Aspects of students interest were measured using Student Like Learning Scale (BSBGSLP); Attitudes toward the importance of physics were measured using the Student Value Science Scale (BSBGSVLP); Students' self-confidence were measured using Student Confidence in Physics Scale (BSBGSCP); Students involvement in physics learning were measured using Student Engaged in Physics lesson Scale (BSBGEPL); and students physics achievement were measured using the average of 5 plausible physics scores (BSSPHY). Students Like Learning Scale consists of 5 items, Student Value Science Scale consists of 6 items, Student Confidence in Physics Scale consists of 6 items, and Student Engaged in Physics comprises of 5 items. All item composing questionnaires or tests have been tested and validated using Item Response Theory.

This study uses path analysis and followed by structural equation modeling (SEM) aided by software of LISREL 8.30. Path analysis is used to find the influence of the variables that directly or indirectly affect the physics achievement while SEM is used for confirmation of the hypothetical theoretical model. Path analysis uses to analyze the relationship between complex variables that can not be done with multiple regressions. In a complex relationship, there is more than one dependent variable so it takes a series of regression equations (Gudono, 2011: 218). In the model proposed in this study did not test the validity of items of each variable with factor analysis since all items used in the TIMSS study were validated previously using Item Response Theory

**RESULTS AND DISCUSSION**

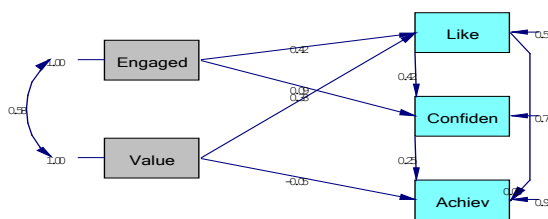
Based on a number of 42 participating countries TIMSS 2011 for grade 8, there are 16 countries that presents physics, chemistry, and biology as separate subjects and there are 26 countries that serve it as an integrated science. Indonesia is one of the countries that presents physics as a separate subject (prior to the enactment of the 2013 curriculum). The ranking of aspects of Indonesian self-interest,

self-confidence and self-involvement in physics learning based on the 2011 TIMSS study from 16 countries can be seen in Table 1.

**Table 1.** interest, confidence and self-involvement in Indonesian student physics leaning in the 2011 TIMSS study.

Variables	Ranks
Student Learning Physics	14
Students' attitudes toward the importance of physics	11
Confident students in learning physics	16

To facilitate analysis in SEM, physics learning interest variable abbreviated as Like, student attitudes toward the importance of physics with Value, confident in studying physics with Confident, and for student involvement in physics lesson with Engaged. The result of SEM analysis with LISREL 8.30 software can be seen in Figure 2. Criteria for goodness of fit test (GFT) of the model can be seen in Table 2.



**Figure 2.** The Theoretical Model of Physics Achievement of Indonesian Students Grade 8 (Standardized, n = 4572)

Figure 2 illustrates the theoretical model of physics achievement of 8th grade Indonesian students in TIMSS 2011 study. Physics achievement model of Indonesian students based on TIMSS 2011 results in Figure 2 can be explained as follows: (1) students' attitudes toward the importance of physics and student involvement have a direct positive impact on interest Students; (2) student involvement has a direct positive impact on confidence; (3) student interest has a direct positive impact on confidence; (4) students' self-confidence and student interest positively affect the physics achievement; (5) attitudes toward the importance of physics have a direct negative impact on physics achievement; (6) student involvement and attitudes toward the importance of physics correlate strongly enough. All relationships between va-

**Table 2.** Several Goodness of Fit Test (GFT) measures in SEM

Size of GFT	Test Criteria	Results	Conclusion
P value	$\geq 0.05$	0.93	model very good fit
$\lambda^2 / df$	$\leq 2$	0.075	model very good fit
Size of GFT	Test Criteria	Results	Conclusion
Root Mean Square Error of Approximation (RMSEA)	$\leq 0.08$	0.000	model very good fit
Goodness of fit index (GFI)	$\geq 0.9$	1	model very good fit
Adjusted Goodness of fit index (AGFI)	$\geq 0.9$	1	model very good fit
Comparative fit index (CFI)	$\geq 0.9$	1	model very good fit
Normal fit index (NFI)	$\geq 0.9$	1	model very good fit
Non Normal fit index (NNFI)	$\geq 0.9$	1	model very good fit

( Kusunendi, 2008 ; Ghozali & Fuad, 2005)

riables as shown in Figure 1 are signified at the 95% confidence level as shown by Table 2. The quantity of direct or indirect impacts between the variables involved can be seen in Table 3 whereas the correlation between the dependent and independent variables can be seen in Table 4.

Based on all the parameters as described by Table 2 shows that based on the nine criteria, the results of SEM analysis can be declared acceptable even to complete. One character of the Likelihood Ratio Test ( $\lambda^2$ ) is the higher the value the relatively low P-count value will be generated, and vice versa. Very much expected Likelihood Ratio Test as small so that the value of P becomes large. Other characteristics of  $\lambda^2$  statistics are sensitive to sample size (Schumaker & Lomax, 1996; Hair, et al., 1998). The larger the sample size the  $\lambda^2$  statistic obtained tends to increase with smaller P-values, so that for large sample sizes the statistics  $\lambda^2$  tend to reject the model (Joreskog & Sorbom, 1996). But apparently it does not occur in SEM analysis conducted in this study, with the sample size of 4572 value  $\lambda^2$  is 0 and the value of P approaches 1 one that is equal to 0.93. This shows that the model produced in this research has high absolute fit measure (AFM). AFM informed the model's ability to accurately estimate the population covariance matrix based on the sample covariance matrix. The two most salient measure of absolute suitability of the LISREL version are Likelihood Ratio Test ( $\lambda^2$ ) and Root means Square Error of Approximation (RMSEA) (Joreskog & Sorbom, 1996).

The result of SEM analysis according to Figure 2 shows that: (1) physics achievement

is directly influenced positively by students' self-confidence and student's interest to learn physics respectively equal to 0.25 (6.25%) and 0.08 (0.64%); (2) physics achievement influenced directly by negative attitude of student toward physics significance equal to -0.05 (0,25%) but indirectly have positive impact equal to 0.06 (0.36%) through student's interest to learn physics and students' confident; (3) physics achievement influenced indirectly positively by student interest in physics learning equal to 0.10 (1%) through student self-confidence; (4) physics achievement is positively indirectly influenced by 0.10 (0.1%) by students 'self-involvement in physics learning through the students' learning interest in physics and self-confidence; (5) students' self-confidence in physics learning was directly influenced positively by the interest of physics study and self-involvement of students in physics learning respectively 0.42 (17.64%) and 0.09 (0.81%); (6) students' interest in physics learning is directly influenced by students' self-involvement in physics learning and students' attitudes toward the importance of physics respectively 0.42 (17.64%) and 0.33 (10.89%); (7) students 'self-involvement in physics learning is positively correlated by 0.58 with students' attitudes toward the importance of physics. The correlation of 0.58 between these independent variables does not interfere with the assumption of multicollinearity (Kusunendi, 2008).

The results showed that students' self-confidence is very dominant influence on physics learning achievement. This is in line with most of the results of research as is demonstrated by Wilkins, et al. (2002), Shen and Tam (2008), Puspendik (2010), Fathi et al., (2013),



**Table 3.** Estimation and Testing Parameter Model Achievement of Physics Learning

Model	Estimation	t	ErrorVar	R <sup>2</sup>
Engaged → Like	0.42	30.65	0.01	0.1764
Engaged → Confident	0.09	5.73	0.02	0.0081
Value → Like	0.33	24.21	0.01	0.1089
Value → Achiev	-0.05	-2.93	0.78	0.0025
Like → Confident	0.42	25.98	0.02	0.1764
Confident → Achiev	0.25	15.57	0.66	0.0625
Like → Achiev	0.08	4.14	1.00	0.0064

Value of t table of 95% and n>30 is ± 2.00

**Table 4.** Influence of Variable Decomposition of Physics Learning Achievement Model

Variabel Influence	Influence		
	Directly	Indirectly	Total
Engaged → Like	0.42	-	0.42
Value → Like	0.33	-	0.33
Like → Confiden	0.42	-	0.42
Engaged → Confiden	0.09	0.18	0.27
Like → Achiev	0.08	0.10	0.18
Confiden → Achiev	0.25	-	0.25
Engaged → Achiev	-	0.10	0.10
Value → Achiev	-0.05	0.06	0.01

**Table 5.** Correlation Matrix of dependent variable and independent variable

	Like	Confident	Achiev	Engaged	Value
Like	1				
Confident	0.48	1			
Achiev	0.17	0.27	1		
Engaged	0.61	0.35	0.11	1	
Value	0.57	0.30	0.07	0.58	1

Mujtaba & Reiss (2014), as well as Topcu, et al. (2016) researches. It can also be seen from the students' confident correlations in physics learning with high physics achievements as described in Table 5. Confidence is also strongly influenced by students' interests and students' interests strongly influenced by students' involvement and student attitudes toward the importance of physics.

Student involvement in physics learning has no direct impact on physics achievement, but still has an indirect impact of 0.1 through students' interest and confidence. This is in accordance with research Mujtaba & Reiss (2014) and research results Perez et al, (2012) where student involvement in learning is one of the factors that affect learning achievement. Willms's

research (2003) on PISA data also proves that student involvement has a strong correlation to science literacy. The results of this study also shows that attitudes toward the importance of physics have a direct negative impact on the achievement of walaupaun is very small only -0.05 while the indirect influence through interest in physics and self-confidence is only 0.01. The results of this study differ from some previous studies. Vahedi & Yari (2014) and Fathi et al. (2013) have reported that students' attitudes toward the importance of physics directly affect physics achievement. However, the results of Puspendik (2010) studying the results of TIMSS 2007 concluded that students' attitudes toward the importance of science influence attitudes toward science lessons but have no

direct impact on science learning achievement. Thus it can be concluded if attitudes toward the importance of physics have a weak influence on physics achievement for Indonesian students.

Indonesian students' interest in physics, according to TIMSS 2011 results, is the latest ranking of 16 countries that teach physics separately. This is truly a serious problem that must be addressed immediately because the results of the study indicated that the interest in physics study has a strong correlation with self-confident, involvement in physics learning, and students' attitudes toward the importance of physics (Table 4) which also corresponds to the research of Akarsa & Kariper (2013). According to the four correlated variables, it can be concluded that students' attitudes toward the importance of physics and student involvement strong enough influence on student interest and subsequently the student's interest is strong enough to confidence and finally self-confident students influential strong enough to the achievement of physics. From this relationship, students' attitudes toward the importance of physics need to be grown in order to build a high learning interest in physics learning. To cultivate a positive attitude toward the subject of physics, the students' perception of physics needs to be encouraged and motivated. Concern of the improvement of students' interest is important because in general students perceive physics learning as a complex and difficult to follow (Cetin, 2016). Santiboon, et al. (2012) stated that the improvement of physics laboratory facilities can enhance students' perceptions of physics learning. Not only in physics, improvement of students' interest in physics and learning motivation also impactful in improving science achievement in general (Rana, et al., 2015).

The facts about the increased involvement of students in physics lessons have been revealed through the innovation of physics-based learning model of students' activity which has a positive impact on student achievement about physics concept (Hatika, 2016, Pratiwi & Muslim, 2016; Damawati & Juanda, 2016; Siswanto, Et al., 2016; Ismawati, et al., 2014; Bautista, 2012). Similarly, the creativity of media usage and assessment model involving students in more intensive ways can improve physics learning achievement (Gunawan, et al., 2016; Shanti, et al., 2014; Nuryantini, et al.,

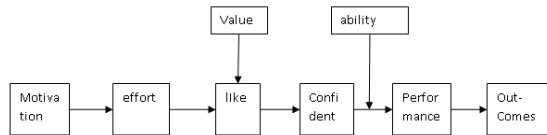
2015). The involvement of Indonesian students in physics learning needs to be improved again by applying various strategies and learning models. This is because in accordance with the results of TIMSS 2011, the achievement of Indonesian students is still ranked 15th out of 16 countries that teach physics separately.

Aspects that determine the achievement of students in learning physics is the students' self-confident. Therefore, efforts to increase students' self-confident are very important to be the main educators' concern. The TIMSS 2011 survey results show that Indonesian students have the lowest confident level, which is ranked 16th out of 16 participating countries that present physics separately. In fact, many learning models can be applied to improve students' self-confident in physics learning, such as the use of generative learning models (Yulianti, et al., 2015), problem-based learning (Wiratmaja, et al., 2014), and blended cooperative learning (Jarnawi & Untara, 2016).

## CONCLUSION

Physics achievement model of Indonesian students based on TIMSS 2011 results are as follows: (1) students' attitudes toward the importance of physics and student involvement have a direct positive effect on student interest; (2) student involvement has a direct positive effect on confident; (3) student interest has a direct positive effect on confident; (4) students' self-confident and student interest positively affect the physics achievement; (5) attitudes toward the importance of physics have a direct but negative effect on physics achievement; (6) student involvement and attitudes toward the importance of physics correlate strongly enough.

Student achievement of physics is influenced indirectly by the involvement of students in physics learning which is indicated through interest and confident in learning physics. Attitudes toward the importance of physics have an indirectly positive effect on physics learning achievement. Students' self-confident in physics learning has the strongest direct influence beyond interest and confident. Dealing with results as Figure 1 (Porter & Lawler in Taylor, 2007), the relationships between motivation and learning outcomes can be shown in Figure 3.



**Figure 3.** The relationships between motivation and learning outcomes from Indonesian Students' Physics Achievement In TIMSS 2011

The results of the study provide recommendations that in the future it can be developed learning model based on student involvement in learning; cultivate a high interest in learning physics; as well as fostering a great student confident in learning physics. Positive attitudes about the importance of physics also need to be developed and grown in the students so as to support the involvement and interest of students in learning physics.

### REFERENCES

Akarsu,B And Kariper,A. (2013). Upper secondary school pupils' attitudes towards natural science. *European Journal of Physics Education*, 4(1),78-87.

Ariyo, A. O. & Ibeagha, E.J.(2008). A path analytical study of Nigerian senior secondary school students'. *Journal of Science Education*, 9(1), 44.

Bautista,R.G.(2012). The impacts of personalized instruction on the academic achievement of students in physics.*International Journal of Arts & Sciences*, 5(5):573–583.

Çetin,A.(2016). An analysis of metaphors used by high school students to describe physics, physics lesson and physics teacher. *European Journal of Physics Education*, 7(2) .1309-7202

Damawati,N.A.C and Juanda,A. (2016). The impact of inquiry based learning on the reasoning ability of grade vii students about heat concept. *Jurnal Pendidikan Fisika Indonesia*, 12 (1),19-25.

Fathi,A, Teimori, N, Malekirad,A.A, Azar,E,F,Poorbaghban,H, Mohamadi, K.A & Shahdosti,L. (2013). Predicting variables of academic achievement and science self-concept of students in third year guidance school based on parents' education level and attitude towards science. *European Online Journal of Natural and Social Sciences* , 2 (2) , 417-425. Special Issue on Teaching and Learning

Ghozali, I & Fuad.(2005).*Structural equation modeling* , Semarang: Badan penerbitan Universitas Diponegoro

Gudono.( 2011). *Analisis data multivariate*, Yogyakarta: BPFE

Gunawan, Harjono,A and Imran. (2016). Pengaruh multimedia interaktif dan gaya belajar terha-

dap penguasaan konsep kalor siswa.*Jurnal Pendidikan Fisika Indonesia*,12(2),118-125.

Gustafsson, J.-E., & Undheim, J. O. (1996). Individual differences in cognitive functions. In *D. Berliner, & R. Calfee (Eds.), Handbook of Educational Psychology*, New York: Macmillan, 1996, pp. 186–242.

Hair , J.F , Anderson , R.E ,Tatham, R.L, & Black , W.C (1998).*Multivariate data analysis* (5<sup>th</sup> etn). Prentice Hall International: UK

Hatika,R.G.(2016). Peningkatan hasil belajar fisika dengan menerapkan model pembelajaran advance organizer berbantu animasi komputer. *Jurnal Pendidikan Fisika Indonesia*,12(2),113-117

Heyneman,S.P.(1997). Jim coleman: a personal story.*Educational Researcher*, 26(1),28-30.

Ismawati,F, Nugroho, S.E, Dwijananti,P .(2014). Penerapan model pembelajaran conceptual understanding procedures untuk meningkatkan curiosity dan pemahaman konsep siswa. *Jurnal Pendidikan Fisika Indonesia* 10 (1) , 22-27

Jarnawi, M &Untara, K.A.A.(2016). Pengaruh penerapan pembelajaran *blended cooperative e-learning* terhadap *self-efficacy* dan *curiosity* siswa dalam pelajaran fisika di sma karuna dipa palu. *Jurnal Pendidikan Fisika Tadulako (JPFT)*, 4 ( 3).

Joncas, M.(2011). *TIMSS 2011 target population sizes* . Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Joncas, M., & Foy, P. (2012). Sample design in TIMSS and PIRLS. In Martin, M.O. & Mullis, I.V.S. (Eds.). (2012). *Methods and procedures in TIMSS and PIRLS 2011*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Joreskog, K.G & Sorbom, D .(1996). *LISREL 8: User's reference guide*. Chicago: Scientific Software International

Kusnendi .(2008).*Model-model persamaan Struktural* , Bandung: Alfabeta

Mujtaba,T& Reiss,M.J.(2014). A survey of psychological, motivational, family and perceptions of physics education factors that explain 15 year-old students' aspirations to study post-compulsory physicsin English schools. *International Journal of Science and Mathematics Education*, April 2014, Volume 12, Issue 2, 371–393.

Martin, M. O ,Mullis, I. V. S., Foy, P., &Stanco,G.M. (2012). *TIMSS 2011 International Results in science*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Mullis, I. V. S., Martin, M. O., Minnich, C. A., Stanco, G. M., Arora, A., Centurino, V. A. S., & Castle, C. E. (eds.) .(2012). *TIMSS 2011 Encyclopedia: Education Policy and Curriculum in Mathematics and Science (Volumes 1 and 2)*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

- Nuryantini, A.Y. , Setiadi,T., Kurniawan, Farida,I. (2015). The application of authentic assessment with feedback to improve the competence of MTS students in constructing a scientific report of motion material in science learning. *Jurnal Pendidikan Fisika Indonesia*, 11 (2) 108-116
- Paik, S. J. (2004). Korean and US families, school and learning. *International Journal of Educational Research*, 41(1), 71–90.
- Perez, P.M., Costa, J.L.C., Corbi.(2012). An explanatory model of academic achievement based on aptitudes ,goal orientations,self-concept and learning strategies. *The Spanish Journal of Psychology*, 15 (1).48-60.
- Pusat Penilaian Pendidikan.(2010). *Determinants of learning outcomes an analysis using data from the trends in international mathematics and science study (timss) 2007*.Research Report. Kementerian Pendidikan Nasional Republik Indonesia.
- Pratiwi, T.R and Muslim.(2016). ppUsing integrated type on science learning for improving junior high school students'critical thinking skills. *Jurnal Pendidikan Fisika Indonesia*, 12 (1), 54-64.
- Rana,R.A, Mahmood,N & Reid,N .(2015). Motivation and science performance : influence on student learning in science. *Sci.Int(Lahore)*, 27(2),1445-1452.
- Reynolds, A. J., & Walberg, H. J. (1992). A structural model of high school mathematics outcomes. *Journal of Educational Research*, 85, 150-158.
- Santiboon,T.,Chumpolkulwong,S., Yabosdee,P and Klinkaewnarong.(2012). Assessing science students' perceptions in learning activities achievements in physics laboratory classrooms in udon thani rajabhat university. *International Journal of Innovation, Management and Technology*, 3 (2) ,April 2012, 171-180.
- Schumaker, R.E & Lomax,R.G. ( 1996) . *A Beginner's guid to sem* .Jew Jersey: Lawrence Erlbaum Associates,Inc.Pub
- Shanti, , M. R. S., Oktaviara, A., Sutresno, A., Wibowo, N.A.(2014).Pembuatan media pembelajaran pengukuran viskositas dengan menggunakan viskometer dua kumparan dan freewave3. *Jurnal Pendidikan Fisika Indonesia* 10 (1), 28-35.
- Shen, C., & Tam, H. P. (2008). The paradoxical relationship between student achievement and self-perception: a cross-national analysis based on three waves of TIMSS data. *Educational Research and Evaluation: An International Journal on Theory and Practice*, 14(1), 87-100.
- Siswanto,J, Saefan, J, Suparmi, Cari .(2016). The impactiveness of e-lab to improve generic science skills and understanding the concept of physics. *Jurnal Pendidikan Fisika Indonesia*, 12 (1),33-40.
- Susilawati & Muhaimin,A.(2014). Pengaruh penggunaan media riil terhadapketerampilan proses sains dan gaya belajar siswa sekolah menengah kejuruan, *Jurnal Pendidikan Fisika Indonesia*, 10 (1), 47-58.
- Suter,L.E .(2000). Is student achievemmet immutable? Evidence from international studies on schooling and student achievement .*Review of Educational Research*, 70(4),529-545.
- Taylor, D.S.(2007). *The development of a theory of learning performance*. Working Paper. January 2007. Center for Business and Economic Development at Sam Houston State University. 1-20.
- Topçu, M. S. , Erbilgin, E.& Arikan, S.(2016). Factors predicting Turkish and Korean students' science and mathematics achievement in TIMSS 2011. *Eurasia Journal of Mathematics, Science & Technology Education*,12(7), 1711-1737.
- Vahedi,S& Yari,M .(2014).Role of Cognitive and Emotional Factors on Educational Achievement among High School Students in Physics. *European Online Journal of Natural and Social Sciences*, 3(3),572-579.
- Walberg, H. J. (2004). Improving educational productivity: An assessment of extant research. *The LSS Review*, 3(2), 11-14.
- Wilkins, J. L. M., Zembylas, M., & Travers, K. J. (2002). Investigating correlates of mathematics and science literacy in the final year of secondary school. In D. F. Robataille & A. E. Beaton (Eds.), *Secondary analysis of the TIMSS data* (pp. 291-316). Boston, MA: Kluwer Academic Publishers.
- Willms, J. D. (2003). *Student Engagement at School: A Sense of Belonging and Participation. Results from PISA 2000*. Paris: Organization for Economic Co-operation and Development (OECD) .
- Wiratmaja, C.G.A, Sadia, I.W. Suastra, I. W.(2014). Pengaruh model pembelajaran berbasis masalah terhadap *self-efficacy* dan *emotional intelligence* siswa sma.e-*Journal Program Pascasarjana Universitas Pendidikan Ganesha Program Studi IPA*, 4.
- Yulianti, R, Khanafiyah,S and Putra,M.D.(2016). Learning strategy implementation of generative learning assisted scientist's card to improve self efficacy of junior high school student in class viii. *Jurnal Pendidikan Fisika Indonesia*, 12 (1), 26-32.

## ONLINE-COURSE DEVELOPMENT VIA DISCUSSION-FORUM ON THE STUDENTS OF PHYSIC EDUCATION UNIVERSITAS NEGERI SEMARANG

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### ABSTRACT

Students of Physic Education of Universitas Negeri Semarang often find some difficulties to understand the material. During difficult times, students usually find references on the internet, ask a friend who already understand, or ask a senior friend. Mostly students have a device that can be used to access the internet. *Online*-course via discussion-forum can be used as a discussion facility when they find difficulties to understand. *Online*-course via discussion-forum developed with ADDIE development models that includes the stages of analysis, design, development, implementation, and evaluation. *Online*-course discussion forum contains the list of courses that can be accessed by students via internet through the website [discussion.belajarfisika.web.id](http://discussion.belajarfisika.web.id). Feasibility of *online* course discussion forum was measured through assessment sheets of feasibility test from validators and questionnaire responses from students. The results of the feasibility test from the validator and student responses indicate that criteria are eligible. Results of the questionnaire about students' perceptions of learning through *online* course discussion forum show that Physic Education Students of Universitas Negeri Semarang have good perceptions of learning through *online*-course via discussion-forums.

### ABSTRAK

Mahasiswa Pendidikan Fisika UNNES sering merasa kesulitan memahami materi perkuliahan. Saat mengalami kesulitan, mahasiswa biasanya mencari referensi di internet, bertanya pada teman yang sudah paham, atau bertanya pada kakak angkatan. Mahasiswa memiliki perangkat yang dapat digunakan untuk mengakses internet. Forum diskusi kuliah *online* dapat digunakan sebagai fasilitas diskusi mahasiswa ketika mengalami kesulitan memahami materi. Forum diskusi kuliah *online* dikembangkan dengan model pengembangan ADDIE yang meliputi tahap analisis masalah, desain, pengembangan, penerapan, dan evaluasi. Forum diskusi kuliah *online* berisi daftar mata kuliah yang dapat diakses oleh mahasiswa dengan internet melalui laman [diskusi.belajarfisika.web.id](http://diskusi.belajarfisika.web.id). Kelayakan forum diskusi kuliah *online* diukur melalui lembar penilaian uji kelayakan dari validator dan angket tanggapan dari mahasiswa. Hasil uji kelayakan dari validator dan tanggapan mahasiswa menunjukkan bahwa forum diskusi kuliah *online* termasuk dalam kriteria layak. Hasil angket persepsi mahasiswa tentang belajar melalui forum diskusi kuliah *online* menunjukkan bahwa mahasiswa pendidikan fisika UNNES memiliki persepsi yang baik tentang belajar melalui forum diskusi kuliah *online*.

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**Keywords:** online-discussion; discussion-forum; perception

### INTRODUCTION

Interviews with some students indicated that they felt that the time for face-to-face lessons was inadequate for the delivery of course

materials. Students found it difficult to understand the lecture material.

When experiencing difficulties, students usually look for references from the internet, ask friends who already understand, or ask senior friends. Therefore, it is necessary to have a discussion forum that can accommodate the

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questions of students who have difficulties related to the lecture material that is submitted to other students so that other students who have mastered can help provide the settlement.

Constructivism learning theory states that students should be active in shaping their knowledge (Baharuddin & Wahyuni, 2008). Therefore, the learning process is expected to encourage students to actively construct their knowledge, not just receiving information. One of the ways for active knowledge-building can be done by interacting with other students.

Discussion is one example of the application of constructivism learning theory in learning (Schunk, 2012). According to Hasibuan & Moedjiono's theory (2006), the discussion is a visual process two or more individuals who interact verbally and with each other face to face about the goals or objectives that have been specified by way of exchange of information, maintains opinions, or problem solving. Discussion can encourage interaction between students as well as between students and teachers. With this interaction, students will get an opportunity to express their opinions and hear the opinions of friends so as to know various points of view to solve the problem.

The definition of Hasibuan & Moedjiono contains face-to-face phrases so it can be said to be a traditional discussion or class discussion. Traditional discussion has several disadvantages. The problems of the traditional discussion of which requires participants to gather in one place and time limited discussion (Meyer, 2003), especially if the discussion carried out when the lecture. The weakness of the traditional discussion can be solved by online-discussion. The advantages of online-discussion are giving the freedom of time and place to start or respond to a discussion, giving time to reflect and think, and discussion can be archived (Th ompson, 2005 and Meyer, 2003).

The online-course via discussion-forum accessed via the Internet can facilitate the interaction between students and make students active in their learning through online-discussion. Online-course via discussion-forum is one form of the website. Aladwani & Palvia (2001) stated that the quality of the *website* includes technical aspects, content and design. Levine (2007) provides conditions that can be used as a guide to keep online discussions can be used effectively. Ten of these conditions namely: (1) create an atmosphere that is condusif for learning, (2) set the rules and provide instruction on opening, (3) convey meaningful questions

and issues, (4) focus on three highest levels of the cognitive domain, (5) guide continuity of discussion, (6) give advocates thinking, (7) appreciate individuality without isolation, (8) being sensitive to nonparticipants, (9) encourage participation, and (10) summarize the main idea.

Interaction facility of online-course discussion forum allowing students to interact in a discussion without limitation of time and place and give it time to think before giving opinion. The archive facility allows students to review the content of the discussion. Interaction and archive facilities contained in a online-course via discussion-forum can help students in their learning.

The number of Internet users continues to increase. Based on the data of Indonesia Internet User Profiles 2014, the number of internet users in Indonesia as much as 88.1 million people until the end of 2014 from 252.4 million people of the population. 18% of the total internet users are students. One use of the Internet is for online forums / online communities 4.3% (APJII, 2015).

The results of early research in 45 students of Physical Education at UNNES (Universitas Negeri Semarang) provide information that they have a device that can be used to access the Internet. Currently, Physic Education students of UNNES utilize social media to share information about activities or events organized by student organizations. Not yet available facilities devoted to the discussion of course materials for students of Physics Education of UNNES. Mazzolini's research (2002) states that on the use of online discussion-forum on Astronomy program showed that students feel comfortable because it can contribute to the online discussion-forum.

Based on the data above, it is necessary to develop an online discussion forum for students of Physic Education at UNNES.

This research aims to develop an online-course via discussion-forum, determine the feasibility of online-course via discussion-forum, and know the perception of Physic Education students about learning through online-course via discussion-forums.

## METHOD

This study was conducted by research and development. Methods used to produce a particular product, and test the effectiveness of the product (Sugiyono, 2013). The product resulting from this study is a online-course via

discussion-forum for students of Physic Educa- tion.

The study was conducted in the Depart- ment of Physics at UNNES in the semester of the academic year 2016/2017. The subject of this study is online-course via discussion-forum of Physic Education students at UNNES. The object of the study examined the feasibility of online-course via discussion-forum of Phy- sic Education Students at UNNES, students' responses and students' perceptions about learning through online-course via discussion-forum. The respondents were divided into two groups, namely the validator group and the user group. Respondents were selected using *purposive* system. *Purposive* system is a sys- tem to determine the respondents with certain consideration (Sugiyono, 2010). In this study the validator group is lecturer of the Depart- ment of Physics at UNNES. Validator is chosen based on scientific background and education and profession. The selected user group is student of Physic Education has taken advantage of online-course via discussion-forum of the three forces. The user group is selected only from UNNES because in this study the user group will be given a written questionnaires. Questionnaires given are questionnaires which contain students' responses and students' perceptions about learning through online-course via discussion-forum. In the students' percep- tions questionnaire about learning through online-course via discussion-forum, there are aspects to facilitate the study of physics.

The development in this research uses the modified ADDIE model from Arkün & Ak- koyunlu (2008). ADDIE includes phase *analy- sis* (analysis of the problem), *design* (design), *development* (development), *implementation* (implementation), and *evaluation* (evaluation).

This research uses two methods of data collection namely assessment sheet and ques- tionnaire. Assessment sheet is used to assess the feasibility of an online-course via discus- sion-forum. The assessment sheet is given to the validator. The assessment sheet of online- course via discussion-forum covering technical aspects, content and design. Election aspects of the assessment based on the criteria devel- oped by Aladwani *website* & Palvia (2001).

Questionnaire is a technique of data col- lection is done by giving a set of questions or a written statement to the respondent to be answered (Sugiyono, 2013). Questionnaire in this research use likert scale 1-5. Questionnaire is used to determine the response of students

to online-course via discussion-forum and students' perceptions about learning through online-course via discussion-forum. Students' responses questionnaire covering technical aspects, content and design of online-course via discussion-forum. Questionnaire percep- tion includes aspects of ease of use, level of interactivity, comfort in physics learning, ease in physics learning, and advanced use.

Analysis was performed on the data ob- tained from the assessment of the feasibility online-course via discussion-forum validator, the response of students to online-course via discussion-forum, as well as the perceptions of students about learning through online-course via discussion-forum. The level of product feasibility, students' responses and students' perceptions is calculated with percentage. Ac- cording to Sudijono's theory (2003), to obtain a percentage of a value can be calculated using equation (1).

$$P = \frac{F}{N} \times 100\% \tag{1}$$

Information:

*P* : Percentage rate (%)

*F* : The amount sought score percentage

*N* : Total score

Results obtained from calculation is converted into qualitative criteria. Criteria for eligibility levels and responses online-course via discus- sion-forum:

84% <value ≤ 100% = Very Eligible

68% <value ≤ 84% = Eligible

52% <value ≤ 68% = Enough

36% <value ≤ 52% = Less Eligible

20% ≤ value ≤ 36% = Not Eligible

Criteria for students' perceptions of learning in online-course via discussion-forum:

84% <value ≤ 100% = Very Good

68% <value ≤ 84% = Good

52% <value ≤ 68% = Good Enough

36% <value ≤ 52% = Less Good

20% ≤ value ≤ 36% = Not Good

(Directorate Technical High School, 2010)

## RESULTS AND DISCUSSION

online-course via discussion-forum was developed by using ADDIE development model of Arkün & Akkoyunlu (2008) which is modified. ADDIE Model includes phase *analysis* (analy- sis of the problem), *design* (design), *develop- ment* (development), *implementation* (imple- mentation), and *evaluation* (evaluation).

## Problem analysis

Analysis in this research is done to know the problem and potency. Therefore, it is conducted interviews and questionnaires to students of Physics Education. Interviews showed the problems experienced by students of Physical Education that is difficult to understand the lecture material. The results of the questionnaire administration demonstrate the potential that is possible to access the facility via the Internet. From problems and potential points, the researchers developed the online-course via discussion-forum. online-course via discussion-forum is expected to be used by students of Physic Education at UNNES (Semarang State University) for discussions related to the lecture material so that it can overcome the difficulties in understanding the lecture material. online-course via discussion-forum developed can be accessed through a *web browser* with a specific domain address. This forum contains a list of courses that can be used for discussion in the appropriate courses.

The development of online-course via discussion-forum using the CMS forum phpBB. PhpBB modified to be suitable for use as a online course discussion forum. For this development, the software used is

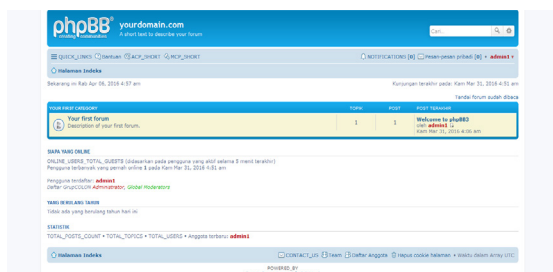


Figure 1. Results of phpBB installation.

- PhpBB 3.1.8 Ascracus,
- Notepad ++,
- XAMPP,
- *web browsers*,
- Domain, and
- *web hosting*.
- PhpBB 3.1.8 can be downloaded in the yard <https://www.phpbb.com/downloads/>.
- The system needed to use phpBB 3.1.8 is as follows.
- *Web server* that supports PHP.
- PHP version 5.3.3 or above.

The SQL database system, for MySQL version 3.23 or above.

## Designing

After the problem analysis is complete, the product design begins. Product design starts with phpBB installation. The initial installation results in Indonesian are shown in Figure 1.

### Counters Number User Login

It is important for a system to document the activities that the user of the system performs. One of them is to find out how often the user is *logged* into the system. The counter number of user login is placed on the file `function.php` file includes folder and inserted into the function `login_box` in logic of `login_success`. Earlier, also added a column in the table `user_login_count` users. *Flowchart* user login number counter is shown in Figure 2.

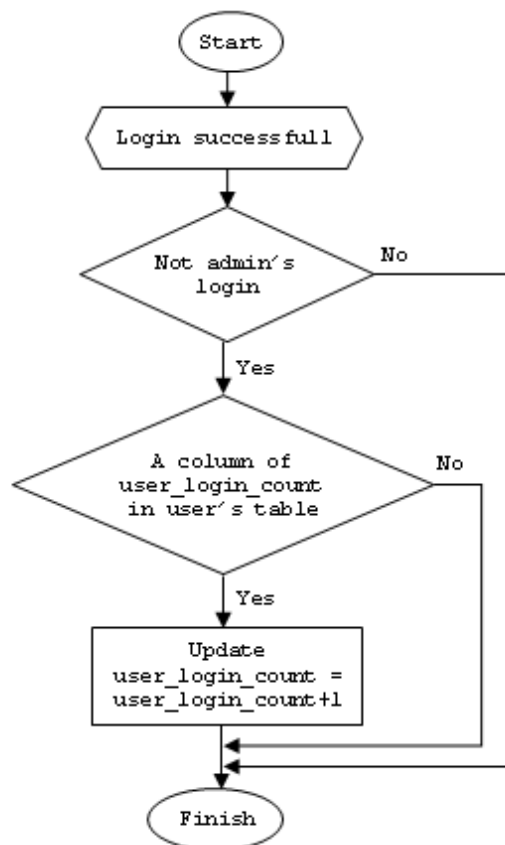


Figure 2. Flowchart user login number counter.

### User Registrant Viewing Submitter

Levine (2007) revealed that there are participants who are not overactive deliver the submissions but always follow the discussion or just reading posts from friends. This statement is also supported by research conducted by Cheng, Collimore, & Joordens (2011) showed that participation in online-course via dis-



discussion-forum mostly only see posts without express opinion. Therefore, it is necessary to create a recorder of the participants who see the submissions. In the installation results, the new phpBB provides a function that calculates the frequency of topics seen by the user. There is no list of usernames that see the topic yet. The function to record users viewing a topic is placed in the viewtopic.php file. Previously, also added table topic\_user\_views. Flowchart of the function is shown in Figure 3.

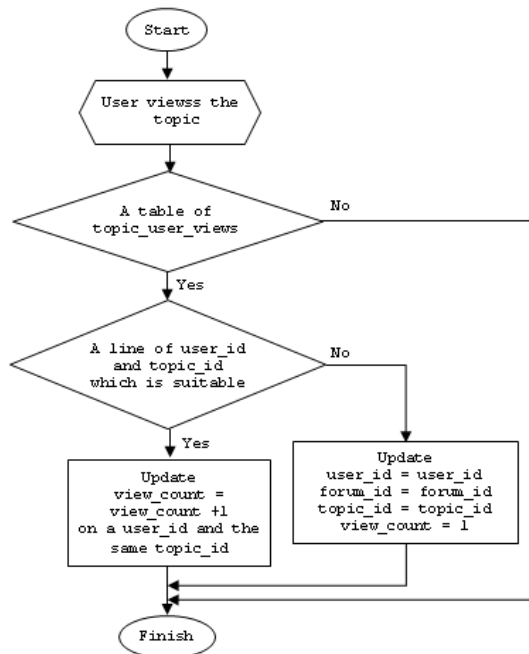


Figure 3. Flowchart of user registrant viewing submitter.

**Development**

Development stage is done by following steps.

**Product Making**

Product design results serve as a reference for product creation. Here is a description of the product manufacturing process.

**Theme Replacement**

From the various themes available in the community of phpBB developers, researchers use a universal theme as a substitute for the prosilver theme. This theme was developed by Inventea. The universal theme code package we can download from [https://www.phpbb.com/customise/db/style/we\\_universal/](https://www.phpbb.com/customise/db/style/we_universal/). Section *headers* are adjusted to better show the identity of physics. The result of the theme adjustment is shown in Figure 4.

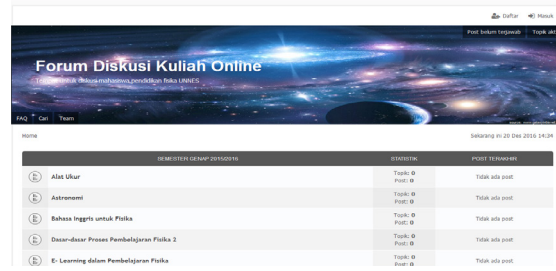


Figure 4. Display of online discussion forum.

**Adjustments Language**

The phpBB developer community has translated the language from the installation to various languages. From the data of the community, the results obtained <https://www.phpbb.com/customise/db/translation/indonesian/> page translation into Indonesian by Sastra Manurung. However, this translation was last updated in 2011 so that there are parts that are less appropriate or not yet available for phpBB version 3.1.8. The researcher corrects and adds translations so that the entire phpBB display appears in Indonesian.

**BBcode for Mathematical Equations**

The phpBB extension developer Marco van Oort and sergio91pt have created an extension that can connect MathJax with phpBB. This extension code is downloaded from [https://github.com/marcovo/phpbb\\_mathjax](https://github.com/marcovo/phpbb_mathjax). MathJax is a JavaScript program for displaying mathematical equations on the website. With MathJax integration with phpBB, a user can write the equation in the form of latex. Once sent, the latex code would appear to be a mathematical equation. The result of the addition of the latex BBcode and the example of its use is shown in Figure 5 in the red circled plane.

To provide instructions for writing formulas on submissions, a guide to writing formulas in the FAQ is prepared. To be less meet the FAQ section, complete instructions write a formula created in the form of *links* connected with the *files* on google drive.

**BBCode to Embed Video**

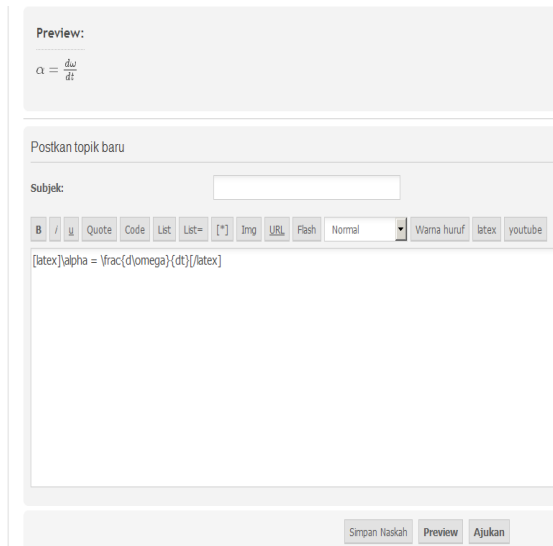
The result of adding BBCode *embed* video and examples of its use is shown in Figure 6.

**Counter of User Login Count**

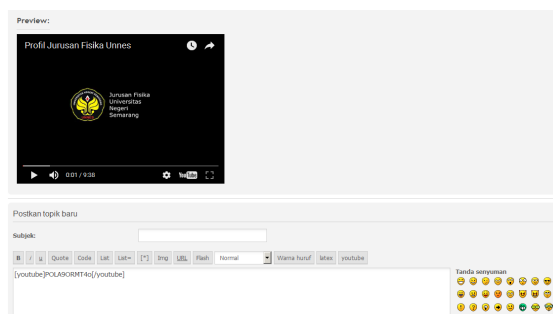
Counters *log* the number of users created by the flowchart in Figure 2. This function will record each time a user successfully logs in to the online-course via discussion-forum.

### User Registrant Viewing Submitter

Registrars users who viewed submissions made by *the flowchart* in Figure 3. The Registrar of users who viewed submissions will record each user who viewed a topic that has been sent.



**Figure 5.** BBCode latex to write the mathematical equation.



**Figure 6.** BBCode embed video youtube.

The screenshot shows an administrative dashboard titled 'Papan Pengaturan Administrasi'. The main content is a table titled 'Instrumen Aktivitas User' with columns for 'Nama User', 'Jenis', 'Status', 'Tanggal', 'Waktu', 'IP Address', and 'Aksi'. The table contains multiple rows of user activity data.

Nama User	Jenis	Status	Tanggal	Waktu	IP Address	Aksi
0001100001	0001100001	0	0	0	0	0
0001100002	0001100002	0	0	0	0	0
0001100003	0001100003	0	0	0	0	0
0001100004	0001100004	0	0	0	0	0
0001100005	0001100005	0	0	0	0	0
0001100006	0001100006	0	0	0	0	0
0001100007	0001100007	0	0	0	0	0
0001100008	0001100008	0	0	0	0	0
0001100009	0001100009	0	0	0	0	0
0001100010	0001100010	0	0	0	0	0
0001100011	0001100011	0	0	0	0	0
0001100012	0001100012	0	0	0	0	0
0001100013	0001100013	0	0	0	0	0
0001100014	0001100014	0	0	0	0	0
0001100015	0001100015	0	0	0	0	0
0001100016	0001100016	0	0	0	0	0
0001100017	0001100017	0	0	0	0	0
0001100018	0001100018	0	0	0	0	0
0001100019	0001100019	0	0	0	0	0
0001100020	0001100020	0	0	0	0	0
0001100021	0001100021	0	0	0	0	0
0001100022	0001100022	0	0	0	0	0
0001100023	0001100023	0	0	0	0	0
0001100024	0001100024	0	0	0	0	0
0001100025	0001100025	0	0	0	0	0
0001100026	0001100026	0	0	0	0	0
0001100027	0001100027	0	0	0	0	0

**Figure 7.** Instruments of user activity.

### User Activity Instruments, Forum Activities, and Activities on Topics

The user activity tools, activity on the forum, and activity on the topics that have been created are shown in Figure 7. This view can only be accessed by the administrator.

Instrument *user* activity displays a list of

user names, NIM, total *posts*, total *logins*, and an active forum. Active forums show the number of forums that users have used to submit posts. The number of active forums in the form of *link* that if clicked will display a list of names forum where users submit posts and the number of submissions by each user on the forum.

Instrument *user* activity on the forum begins by displaying a selection list of available forums and browse buttons. If the user has selected the forum and pressed the view button, it will show a list containing the users who have submitted the submissions and the number of submissions from each user.

Instrument *user* activity on the topic begins by displaying a selection list of available forums and browse buttons. If the user has selected the forum and pressed the view button, it will show a list of topic options that have been created on the forum and the view button. If the user has selected the topic and pressed the view button, then the active user will appear on the topic either just view the topic or send the post.

The product that has been generated ensures that all parts work. The products were then uploaded to *the web hosting*. *Online* course discussion forum that has been developed can be accessed through *diskusi.belajarfisika.web.id* page or through a google search by keyword *online-course* via *discussion-forum*. *Web servers* are used using PHP version 5.4 and MySQL version 5.6.34. The product database that has been developed has 68 tables because it has been added one table.

### Instrument Making

The instrument was made in this study is the assessment form, questionnaire responses of students, and student perceptions questionnaire about learning through online-course via discussion-forum. The assessment sheets and students' responses questionnaire were based on criteria from Aladwani & Palvia (2001). The instrument used fulfills the validity of the construct.

The assessment sheet has 22 indicators divided into 3 aspects namely technical, content, and design respectively with the number of 8, 6, and 8 indicators. The assessment sheet is attached at Appendix 5. The students' responses questionnaire has 19 indicators which are also divided into 3 aspects namely technical, content and design respectively with 7, 5, and 7 indicators. Students' responses questionnaire attached in Appendix 11. Question-

naire about students' perceptions of learning through online course discussion forum has 11 statements divided into five aspects namely ease of use, level of interactivity, convenience in studying physics, ease in learning physics, and continued use.

**Product Validation**

The results of the product validation conducted by validator states that online-course via discussion-forum included in the criteria developed very decent with a percentage of 84.24%. These results indicate that the online-course via discussion-forum has been developed ready for use.

**Implementation**

Online-course via discussion-forum that has been developed is used by students to discuss at the beginning of odd semester 2016/2017. Users who signed up for the research process and approved as many as 136 users. The courses included in the online-course via discussion-forum are the courses of Physics Education Study Program available in odd semester of 2016/2017 academic year the number of 32 subjects. The entire course is included in the online-course via discussion-forum, not mostly subjects only, in order to facilitate discussions that may occur on all these subjects.

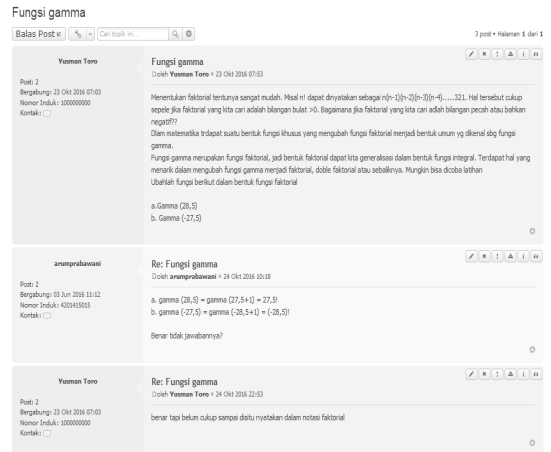
During the study, discussions took place in several subjects, they are Basic Physics 1, Computational Physics, Mathematical Physics 2, and Mechanics 1. The number of topics and submissions in each course and the number of users are shown in Table 1. Examples of discussions that occur as in Figure 8.

Students who have been using online-course via discussion-forum were given a questionnaire about students' responses and students' perceptions of learning through online-course via discussion-forum.

**Evaluation**

At this stage, the analysis of data ob-

tained in the preceding stage is related to the feasibility study online-course via discussion-forum and students' perceptions about learning through online-course via discussion-forum.



**Figure 8.** The Example of discussion.

The results of the data analysis of the feasibility of online-course via discussion-forum are presented in Table 2.

The technical aspects include user data security, ease of operation, availability, functionality link, the browser customization, loading speed, ease of access, and search functions. The results of due diligence on the technical aspects of online course discussion forum validator obtain the percentage of 84.17% with a very decent criteria and feedback of students earn a percentage 77.14% with a decent criteria as in Table 4.2. Online-course via discussion-forum is considered very worthy of study because it is easy to operate, always accessible, all the links work properly, it can be opened in any browser, as well as easy to access. Zhang & Dran (2001) states that the ease of operation and the search function is an important feature of educational websites.

Aspect contents include possible use, usage instructions, developer identity, contact information, FAQs, and registration forms. As-

**Table 1.** Data online discussions.

Courses	Topic	Number of Users Delivering Submissions	Number of Submissions	Number of Users Viewing Topics	Frequency Topic Views
Basic Physics 1	3	4	9	11	41
Computational Physics	1	2	2	6	14
Mathematical Physics 2	3	4	6	5	27
Mechanics 1	1	2	2	4	7
Total	8	12	19	26	89

pects of the contents from online course discussion forum earn a percentage 85.56% with a very decent criteria of due diligence validator and the percentage of 79.03% with a decent criteria of students' responses. This result was obtained because the features in the online-course via discussion-forum supports for the online-discussion. Completeness of a *website* already exist on online-course via discussion-forum, such as FAQs, application forms, and instructions for use.

Aspects of the design include appearance, organization, clarity of text, blend colors, language, *layout*, responsive, and accuracy. The feasibility test result on the design aspect obtained the percentage of 83.33% with the eligible criteria of the validity test and the percentage of 77.92% with the eligible criteria of the students' response. College online discussion forum developed to perform well on a variety of devices used for phpBB has advantages responsive display. In addition, online-course via discussion-forum is well organized so that each topic delivered already at the appropriate courses. This agrees with the results of Wijayati's (2013) study that discussion forums should be well organized through categories that can be selected to suit the topics being discussed. Therefore, a *website* developed be appropriately used for online-course via discussion-forum.

The advice given by the validator on the products developed, namely that online-course via discussion-forum connected by means other notices that more frequently accessed by student. This suggestion is used as reference product revision so that notifications in online-

course via discussion-forum are also delivered via *email* users. The revised to make users aware of the new message notification via *email* without having to open an online-course via discussion-forum page first.

Overall of the technical aspects, content, and design, online-course via discussion-forum developed included in the criteria are eligible with the percentage of 81.08%. These results indicate that the online-course via discussion-forum that has been developed ready for use.

The results of the data analysis physics education students' perception about learning through online-course via discussion-forum are presented in Table 3.

Table 3 shows that ease of use gets the highest percentage of 74.55% with good category obtained from the statement of effectiveness as supporting media lectures and ease of use. These results indicate that the online-course via discussion-forum is easy to use and effective as supporting media lectures. Ease of use got a good category for the display of online-course via discussion-forum is easy to be operated by the user. Research Cheng et al. (2011) showed the same results that the online-course via discussion-forum with phpBB is easy to use and effective for lectures.

Aspects of interactivity level get percentage 68,89% with good category. Aspects of interactivity levels include participation desire, communication skills development, and increased willingness to share lecture materials. Online-course via discussion-forum become a medium for exchanging information. Students who already understand the material or can do

**Table 2.** The test results.

Aspect of Assessment	Validator		Students' Responses	
	Percentage (%)	Criteria	Percentage (%)	Criteria
Technical	84.17	Very Feasible	77.14	Feasible
Content	85.56	Very Feasible	79.03	Feasible
Design	83.33	Feasible	77.92	Feasible
Average	84.24	Very Feasible	77.93	Feasible
Overall	Percentage	81.08	Criteria	Feasible

**Table 3.** Perception of students on learning through *online* course discussion forum.

Aspect of Assessment	Percentage (%)	Criteria
Easy to use	74.55	Good
Interactivity level	68.89	Good
Comfort in learning physics	64.24	Good Enough
Make it easy to learn physics	72.12	Good
Advanced Use	73.64	Good
Overall	70.52	Good

the questions can participate by sharing their understanding. This activity has an impact on students' communication skills. These results conformed with Shana's research (2009) which states that one of the activities that benefit from the online discussion is to interact and share ideas and lecture material.

Comfort in learning physics aspects of obtaining the percentage of 64,24% with good enough category derived from statements of learning more fun and be more likely to learn. This result was obtained because the student participation rate is still low as in Table 1 so that the user can not adjust to the use of online-course via discussion-forum. This is a limitation of research, only a few students participate in the discussion. Student participation in online-course via discussion-forum needs to be a concern, based on Levine's statement (2007) that encourages participants to actively participate in online discussion can be a major challenge. Cheng et al. (2011) in his research that uses an online-discussion forum on the course with voluntary participation, which do not include participation in an online discussion on the assessment format, shows that the number of students that at least convey the items contained only about 11%. Conversely, research Seethamraju (2014), which includes participation in online discussion on the assessment of obtaining high levels of participation that all students participate in the discussion. From the statement above, if you want to obtain a high level of participation, it is recommended that teachers include participation in online discussion to be part of the assessment.

Aspects ease in learning physics earn a percentage 72.12% with both categories. These aspects include an increase in the understanding of the material and do the questions of physics. From some of the discussions that took place, students discussed the problems or tasks that are difficult to work independently. The discussion assist students in understanding the material and do the questions of physics. It is appropriate with Tarin statement's (2005) that the benefits of group discussion include the ability to provide more resources for solving many problems.

It should also be observed on the aspects of the use of advanced also earn a percentage is high at 73.64% with both categories derived from an expression of interest that most of the course utilizing online-course via discussion-forum and will participate actively if the online-course via discussion-forum is

used more for support lectures. This result is an opportunity for teachers to take advantage of online-course via discussion-forum. Shana's study (2009) showed the same results that the students would be happy to participate in the discussion forum based *web* in the future.

From the aspect of ease of use, the level of interactivity, convenience in studying physics, facilitate the study of physics, and the use of advanced, it is obtained by percentage of 70.52% and are included in both criteria. These results indicate that the student has a good perception related learning through online-course via discussion-forum. These results are in line with Wu & Hiltz researchs' (2004) stated that students have a good perception of learning through online discussion .

## CONCLUSION

From this research, it has developed an online-course via discussion-forum with ADDIE development model. The development process includes the stage of problem analysis, design, development, implementation, and evaluation. The result of this development study is an online-course via discussion-forum that can be used by students to discuss physics courses. Online-course discussion forum that meet the criteria are eligible to be developed based on the assessment validator and student feedback. Physical education students' perceptions of learning through online-course via discussion-forum are included in both criteria.

Advice given to further research that it is necessary to socialize on the entire students of physics education so that the participation rate is high, the use of online-course via discussion-forum should involve the lecturer of the course so that the contents of the discussion can be ascertained the truth, the use of online course discussion forum for discussion between students from different universities to facilitate a wider exchange of ideas, as well as further research on the use of online-course via discussion-forum intensely on certain subjects.

## REFERENCES

- Aladwani, A.M., & Palvia, P.C. (2001). Developing and Validating an Instrument for Measuring User-Perceived Web Quality. *Information & Management*, 39 (6): 467-476.
- Arkün, S., & Akkoyunlu, B. (2008). A Study on the Development Process of a Multimedia learning Environment According to the ADDIE Model and Students' Opinions of The Mul-

- timedia Learning Environment. *Interactive Educational Multimedia*, 17: 1-19.
- Asosiasi Penyedia Jasa Internet Indonesia (APJII). (2015). *Profil Pengguna Internet Indonesia 2014*. Online. Retrieved from <https://beta.apjii.or.id/download/file/PROFILPENGGUN-AINTERNETINDONESIA2014.pdf>
- Baharuddin & Wahyuni, E.N. (2008). *Teori Belajar dan Pembelajaran*. Yogyakarta: Ar-Ruzz Media.
- Cheng, C.K., Pare, D.E., Collimore, L.M., & Joordens, S.. (2011). Assessing the effectiveness of a voluntary online discussion forum on improving students' course performance. *Computer & Education*, 56: 253-261.
- Direktorat Pembinaan SMA. (2010). *Juknis Penyusunan Perangkat Penilaian Afektif SMA*. Online. Retrieved from [regulasi.sman1jember.sch.id/index.php?dir=Peraturan+Pemerintah+26%+Menteri%2FPetunjuk+Teknis+dan+Pedoman%2F](http://regulasi.sman1jember.sch.id/index.php?dir=Peraturan+Pemerintah+26%+Menteri%2FPetunjuk+Teknis+dan+Pedoman%2F)
- Hasibuan, J.J., & Moedjiono. (2006). *Proses Belajar Mengajar*. Bandung: Remaja Rosdakarya.
- Levine, S.J. 2007. The Online Discussion Board. *New Directions for Adult and Continuing Education*, 113: 67-74.
- Mazzolini, M. (2002). The Use of Online Discussion Forum as a Learning and Teaching Tool in Astronomy. *Publication of the Astronomical Society of Australia*, 19: 448-454.
- Meyer, K.A. (2003). Face-to-Face Versus Threaded Discussion: The Role of Time and Higher-Order Thinking. *Journal of Asynchronous Learning Networks*, 8 (2): 55-65.
- Schunk, D. H. (2012). *Teori-Teori Pembelajaran: Perspektif Pendidikan* (6<sup>th</sup> ed.). Translated by Hamidah, E. & R. Fajar. Yogyakarta: Pustaka Pelajar.
- Seethamraju, R. (2014). Effectiveness of Using Online Discussion Forum for Case Study Analysis. *Education Research International*, 2014: 1-10. Retrieved from <http://downloads.hindawi.com/journals/edri/2014/589860.pdf>
- Shana, Z. (2009). Learning with Technology: Using Discussion Forums to Augment a Traditional-Style Class. *Educational Technology & Society*, 12 (3): 214-228. Retrieved from [http://www.ifets.info/journals/12\\_3/19.pdf](http://www.ifets.info/journals/12_3/19.pdf)
- Sudijono, A. (2003). *Pengantar Statistik Pendidikan*. Jakarta: Raja Grafindo Persada.
- Sugiyono. (2010). *Statistika untuk Penelitian*. Bandung: Alfabeta.
- Sugiyono. (2013). *Metode Penelitian Pendidikan (Pendekatan Kuantitatif, Kualitatif, dan R&D)*. Bandung: Alfabeta.
- Tarigan, H.G. (2005). *Berbicara sebagai Suatu Keterampilan Berbahasa*. Bandung: Angkasa.
- Thompson, H. (2005). Asynchronous Computer Mediated Communication: Pedagogical Reflections. *Journal of Advanced Technology on Education*, 2 (2): 225-228. Retrieved from <http://www1.aucegypt.edu/faculty/thompson/herbtea/articles/ate.htm>
- Wijayati, K. (2013). *Perancangan dan Pembuatan Forum Diskusi Berbasis Web untuk STMIK Amikom Yogyakarta*. Naskah Publikasi. Sekolah Tinggi Manajemen Informatika dan Komputer Amikom Yogyakarta.
- Wu, D., & Hiltz, S.R., (2004). Predicting Learning from Asynchronous Online Discussions. *Journal of Asynchronous Learning Network*. 8(2), 139-152.
- Zhang, P., & Dran, G. (2001). Expectations and Rankings of Website Quality Features: Results of Two Studies on User Perceptions. *Proceedings of the 34th Hawaii International Conference on System Sciences 2001*. Hawaii: Wailea.

# THE IMPLEMENTATION OF LEARNING DEVICES WITH SCIENTIFIC APPROACH TO IMPROVE STUDENT LIFE SKILLS

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## ABSTRACT

The purpose of this study was to test the effectiveness of the implementation of learning device with scientific approach to improve student life skills. The research uses one group pre test–post test design. Subjects in this study were students of grade ten (class X). Implementation of learning device supports effectively in learning activities if the implementation of a lesson plan by teachers, student social skills and student academic skills at least in a good category. The results showed that the implementation of lesson plan by teachers to get the average value of 3.38 are in the very good category, gain value of the student social skill at average value of 3.03 is in the very good category, and gain of student academic skill at average value of 76 is in the good category. It concludes that the implementation of learning tools with scientific approach support effectively in learning activities.

## ABSTRAK

Tujuan penelitian ini adalah menguji efektivitas implementasi perangkat pembelajaran fisika dengan pendekatan saintifik untuk meningkatkan kecakapan hidup siswa. Penelitian ini menggunakan one group pretest-posttest design. Subjek dalam penelitian ini adalah siswa kelas X. Hasil penelitian menunjukkan bahwa pelaksanaan dari Rencana Pelaksanaan Pembelajaran oleh guru memperoleh nilai rata-rata sebesar 3,38 dan berada pada kategori sangat baik. Kecakapan sosial siswa memperoleh nilai rata-rata sebesar 3,03 dan berada pada kategori sangat baik. Adapun kecakapan akademik siswa memperoleh nilai rata-rata sebesar 76 yang berada pada kategori baik. Berdasarkan hasil-hasil penelitian tersebut dapat diimpuliskan bahwa implementasi perangkat pembelajaran dengan pendekatan saintifik efektif menunjang kegiatan pembelajaran fisika dalam meningkatkan kecakapan hidup siswa.

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**Keywords:** life skills; scientific approach

## INTRODUCTION

Preparation of learning tools is something that must be done by teachers in planning learning activities so that the expected goal can be achieved. According to Ibrahim's theory (2003), a component of the learning device to be prepared by teachers to manage the classroom well is the syllabus, lesson plan, student textbook, student worksheet, learning tools, and final examination. Trianto (2008) and Tim Pustaka Yustisia (2008), write that the syl-

labus is a lesson plan on a particular subject that includes a standard competence, basic competence, subject matter or teaching materials, learning activities, indicators of achievement of competencies, assessment, allocation of time and sources of learning. Lesson plan is a plan for teachers which describes the procedures and organizing the implementation of the learning process to achieve a basic competency that has been defined in the standard content and described in the form of syllabus. Student textbook is a guidebook for students in learning activities containing lesson material, concept-based inquiry activities, experimen-

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tal activities, information, and examples of the application of concepts in everyday life. Student worksheet is a guideline of student work to facilitate students in the implementation of learning activities. Learning tools is a messenger from several sources to the recipient of the message. Final examination is a test item used to determine the student learning outcomes after following the learning activities. In this research, the learning device with scientific approach consisting of syllabus, lesson plans, Student textbook, student worksheet, learning tools and final examination developed with attention to student learning experience that will be gained through the learning process to observe, ask, gather information, associates, and communicate.

The syllabus and lesson plan developed in this study use the 5E learning cycle model (Engage, Explore, Explain, Elaborate, and Evaluate). Scientifically-based student worksheet have components such as experimental titles, purpose of the study, tools and materials, problem formulation, hypotheses, variables, operational definitions of variables, experimental steps, observation data, data analysis, and conclusions. The medium used is a three-dimensional media to assist students in completing the tasks contained in the worksheet. During the learning process with the 5E learning cycle model, teacher makes assessment using observation sheet to the observation skills of the social attitudes of students (social skills). Final examination in the cognitive domain (academic skills) is done after the learning process is complete.

In making learning activities, teachers will define models, approaches, strategies, methods, and techniques of learning what will be used in the implementation of learning. According to Suprihatiningrum's theory (2013), learning model is a design which illustrates a learning process that can be done by teachers in transferring knowledge and values to students. Approach is a common way of looking at the problem or object of study, such as learning. The term learning strategies are used to indicate the overall strategy or activities done by teachers to create learning atmosphere is very conducive to the achievement of educational goals. Learning strategy can be said to be implementation of the learning model. Methods are the ways teachers use to teach students. If a strategy refers to a plan for achieving something, then the method refers to a way that can be used to execute the strategy. The

instructional technique refers to the distinctive variety of the application of a method according to the specific implementation background, such as the teacher's ability and habits, the availability of equipment, the readiness of the students, and so on.

Jufri (2010) states that there are some things that must be considered by teachers in choosing or determining the models, approaches, strategies, methods, and learning techniques to be applied. Things to consider are the learning objectives, activities and initial knowledge of the students, the nature of the learning materials, the allocation of time, the supporting facilities, the number of students, the experience and the authority of the teacher.

In developing learning tools, teachers can use a scientific approach that is expected to provide a learning experience for students so that students' life skills increase. Sani (2014) argues that the scientific approach is closely related to the scientific method. Scientific (scientific) methods generally involve observation or observation activities required for the formulation of hypotheses or collecting data. The scientific method is generally based on the exposure data obtained through research or experiments.

Indonesian Ministry of Education And Culture (2013) mentions that, the scientific approach in learning includes: observing, asking, reasoning, trying, forming networks for all subjects. Learning process with scientific approach touching three domains, namely: attitude, knowledge, and skills, so that the learning outcomes produce students who are productive, creative, innovative, and affective. In other words, the application of scientific approaches to learning, including learning of physics, can improve students' life skills. Machin's research (2014) concludes that the scientific approach brings positive effect on the cognitive learning, affective and psychomotor and have reached the classical completeness set.

Mugambi & Muthui (2013) argue that the life skills curriculum plays a major role in enabling students to use their knowledge, attitudes and values into abilities on what to do and how to do it. This study found several factors that influence the implementation of Life Skills curriculum, namely: teaching approach, lack of life skills conceptualization, limited human resources, lack of supervision, teacher preparation is lacking, lack of choice of teaching and learning strategies, limited use of learning resources, bad assessment, and the students'



negative attitudes toward life skills. Mugambi & Muthui concluded that the implementation of Life Skills Education depends primarily on the competence of teachers, on the other hand, are also influenced by extrinsic factors.

Agustina and Saputra (2012) said that the implementation of life skills-based learning can be done by integrating aspects of Life Skills on subjects in secondary schools, one of them is physics. The problems that arise in the implementation of Life Skills based learning are how to design life skills based learning tools, how to develop life skills based learning activities and how to understand the life skills aspects in each subject and difficulties in integrating every aspects of Life Skills in each subject matter in accordance with the available format.

Life skills-oriented education program through a broad-based approach, or known as the *Broad Base Education* is very possible to be implemented in every type and level of education. In addition to not changing the existing curriculum system, this program does not add to the burden of new subjects, but only change the orientation of the learning program (BBE Team of Ministry of Education, 2012).

Ibnu (2014) argues that the application of a scientific approach in the effort to develop the life skills of students through learning in schools still faces various obstacles, among others are the curriculum targets to pursue material adequacy facing examination (national examination) and policies of educational authorities that are less precise, and public perceptions about the success of education has also been wrong. Parents were more likely to appreciate and be proud of ourselves if their son honored ranks in the classroom, school and even its society rather than to the skills their children to practice the *scientific approach* and *process skills*. It educates children if necessary to take shortcuts to achieve mastery of teaching materials without good learning process.

Development of Life Skills (life skills), especially social skills (skill) and academic skill, in this research is facilitated by the use of student worksheet and learning tools in the form of three dimensional media. Trianto (2008) defines that student worksheet is a student guide that is used to conduct the investigation and problem solving. Sukiman (2012) argues that learning media is anything that can be used to channel the message from the sender to the recipient so as to stimulate the thoughts, feelings, concerns, and interests and willingness of students in such a way that the learning process

occurs in order to achieve the learning objectives effectively. Sudjana & Rivai (2013) states that there are four types of learning media, namely: (1) two-dimensional media or graphic media is a medium that has a length and width such as pictures, photographs, graphs, charts or diagrams, posters, cartoons, comics, and etc. (2) three-dimensional media that is in the form of models such as solid model, cross-section model, stacking model, work model, mock-ups, dioramas, and others. (3) projection media such as slides, film strips, films, use of OHP and others. (4) the environment.

Three-dimensional media as one type of learning media can be a model, that is three-dimensional copy of some real objects that are too big, too far, too small, too expensive, too rare, or too complicated to be brought into the class and studied by students in the form its original (Sudjana & Rivai, 2013). Sudjana & Rivai disclose the benefits of three-dimensional media in the learning process, including physics learning in secondary schools are: First, learning will attract more students so it can foster motivation to learn; Second, teaching materials will be more clear meaning so that it can be more easily understood by students and enable students to master the learning objectives better; Third, teaching methods will become more varied, not merely verbal communication through the words of the words by the teacher, so that students are not bored and the teacher does not run out of energy, especially when the teacher teaches for every lesson; Fourth, students do more learning activities, because not only listen to the teacher's description, but also other activities such as observing, performing, demonstrating, and others.

Three-dimensional media is a potential alternative to increases the quality of teaching physics in high school. A solid model usually shows the outer surface of the object rather than the object and often discards the confusing parts of its main ideas of shape, color, and composition. The cross-sectional model shows how an object is visible, when its surface is lifted to know its inner arrangement. The stacking model consists of several parts of a complete object, or at least an important part of the object. The work model is an imitation of an object that shows the outside of the original object, and has some portion of the real thing. Mock-ups are a simplification of the underlying arrangement of a process or a more intricate system. Diorama is a mini-three-dimensional landscape aimed at describing the true land-

scape. Three-dimensional media that has been developed in this research is three dimensional media "Dynamic Electricity".

According to the World Health Organization (WHO), Life Skills (life skills) is the ability for adaptive behavior, and positive that allows students to deal effectively with the demands and challenges of everyday life. According to the United Nations International Children 's Emergency Fund (UNICEF), Life Skills is a behavioral change or behavioral development approach designed to address the balance of three areas of knowledge, attitude and skills. In other words, life skills are the skills needed to live successful (Khera and Khosla, 2012).

Anwar (2006) and Susiwi (2007) revealed that life skills consist of general life skills (General life skills) and life skills that are specific (Specific life skills). Life skills that are general in nature consist of personal and social skills, while life skills that are specific consist of academic and vocational skills. Personal skills (*personal skills*) consisting of: self-knowledge skills (*self-awareness skills*), and thinking skills (*thinking skills*). Social skills (social skills) comprising: communication skills, and ability to cooperate (*collaboration skills*). Academic skills are also called intellectual skills or scientific thinking skills and are the development of thinking skills. Academic skills have already led to academic or scholarly activities. This skill is important for people who pursue a job that emphasizes thinking skills. Therefore, this skill should get emphasis from the beginning of junior high school and especially on the academic program at the university. Vocational skills are also called vocational skills, these skills are associated with certain occupations in the community. This skill is more suitable for students who will pursue jobs that rely more on psychomotor skills. So this skill is more suitable for Vocational High School students, skill courses or diploma programs. This study aims to test the effectiveness of the implementation of the learning device physics with a scientific approach to increase life skills of students in high school.

## METHOD

The type of research is research development. The learning device which is developed consists of Syllabus, Lesson Plans, Subject Matter Books, Student Worksheet, Three Dimensional Media, and Learning Result Test are integrated with life skills. Learning device

development model used is Four D model (Define, Design, Develop, Disseminate). According to Ibrahim (2003) and Trianto (2008), this model was adapted into model 4 P (Definition, Design, Development, Deployment).

*Define* phase aims to establish and define the requirements needed in learning based on a needs analysis, analysis of student, task analysis, concept analysis, formulation of learning objectives. *Design* phase aims to design *prototype* learning device to do the preparation of lesson plan, the selection of student textbook and student worksheet format, visual three-dimensional model, and final test. *Develop* phase aims to produce learning tools which have been revised based on feedback from the validator. *Disseminate* phase aimed at implementation of the learning tools in the classroom. Phase *Define*, *Design*, and *Development* conducted in the first year.

Test of the effectiveness of the implementation of learning tools in the research (second year) conducted in stages Spread (Disseminate), with the subjek were students of grade ten (Class X) 2<sup>nd</sup> Semester of Academic Year 2015/2016 in Madrasah Aliyah Dakwah Islamiyah Puteri Nurul Hakim Kediri, West Lombok. Research design to test the effectiveness of learning device implementation using One Group Pre-Post test design. According to Arikunto's theory (2006), this design only uses one group only without any comparison group. This design has the disadvantage in terms of testing the effect of independent variables (scientific approach) on the dependent variable (life skills), because it does not use a control group. Therefore, in this study performed a sensitivity analysis items are obtained by the students of the initial test and final test. According to Grounlund (1985) in Ibrahim (2005), the sensitivity index has values from 0 to 1. The value 0 means insensitive, while 1 is very sensitive.

Based on Ibrahim's theory (2005), the sensitivity of a test is the test's ability to measure the learning effect. Question which has sensitivity means the matter can provide information that the measurement result is a result of learning.

Implementation of the learning device with a scientific approach and 5E learning cycle model is said to be effective in this physics study if the implementation of lesson plans by teachers, students' social skills and academic skills of students at least have the good category. Here are the phases of learning with

5E learning cycle model to provide student learning experiences appropriate scientific approaches such as observing, asking, gathering information, associating, and communicating.

**Table 1.** Learning Cycle Model 5E.

Phase	Teacher activity
Engage	Conditioning the students to be ready to follow the lessons by giving demonstrations or questions to determine the ability of the beginning
	Presenting indicators (learning objectives)
Explore	Dividing the students in groups
	Guiding students to work on student worksheet
Explain	Providing an opportunity for group representatives to present their work based on student worksheet
	Explaining or straighten the concept of learning material based on data from student experiments
	Directing student's experiment results to answer problems in preliminary activities
Elaborate	Encouraging students to inquire material that remains poorly understood by asking teachers
	Demonstrating application of concept about learning material in everyday life
	Checking students' understanding of learning materials by asking them back
Evaluate	Guiding students to make conclusions
	Providing follow-up to give the assignment or homework

Implementation of learning with scientific approach and 5E cycle learning model for Dynamic Electrical material conducted during 6 times meeting. The time allocation for each meeting is 2 hours of lesson.

**RESULTS AND DISCUSSION**

Some obstacles / problems can occur in the implementation of learning activities in the classroom, including in physics learning. Akinbobola & Afolabi (2010) mention that the challenge in teaching physics is to create ex-

periences that engage students and how to facilitate students in order to have the skills like observing, measuring, classifying, communicating, concluding, using numbers, using the relationship of space / time, asking questions, controlling and manipulating variables, creating hypotheses, making the operational definition of variables, model making, designing experiments, and interpreting data. According to Oladejo, et.al. (2011), the strategies used by teachers is one of the factors that influence academic achievement that is still lacking in physics lesson.

Implementation of the learning device physics with a scientific approach conducted in six sessions, with the stages of each meeting is to observe, inquire, try (experiment), associate (reasoning), communicate. Learning with a scientific approach is a student-based learning activity. According Bonwell & Eison (1991) in Prince (2004), active learning is a teaching method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they do.

The results of observation on the implementation of Lesson Plan (RPP) by teacher are as follows.

**Table 2.** Implementation of lesson plan by teacher.

Meeting	Score	Criteria
1st	3.58	Very good
2nd	3.50	Very good
3rd	3.42	Very good
4th	3.42	Very good
5th	3.17	Very good
6th	3.17	Very good

The mean adherence to the lesson plan by teacher of 3.38 are in the very good category. This is because the teacher has implemented the learning in accordance with the planning contained in the learning tool with a scientific approach. Stages of learning using a scientific approach have provided a learning experience for students so that students can develop life skills. This is in accordance with regulation of the Indonesian ministry of education No.81A In 2013, Appendix IV, that there is a link between the pace of learning with learning activities and their meanings, as follows.

**Observe**

Learning activities undertaken in the

process of observing are: reading, listening, listening, seeing (without or with tools). The developed competencies are: training in sincerity, thoroughness, seeking information.

### Ask

Questioning learning activities are conducted by asking questions about information that is not understood from what is observed or questions to get additional information about what is observed (starting from factual questions to hypothetical questions). The competencies developed is to develop creativity, curiosity, the ability to formulate questions to establish the critical thinking necessary for intelligent life and lifelong learning.

### Gathering information / Experiments (Trying)

Gathering information / experiments on learning activities include: conducting experiments, reading sources other than textbooks, clicking observe objects / events / activities, and interviews with sources.

Competencies developed in the process of gathering information / experiments are developing a meticulous, honest, courteous attitude, respecting the opinions of others, communication skills, applying information gathering skills through various ways learned, developing lifelong learning and learning habits.

### Associate / Process information

Learning activities undertaken in the process of associating / processing information are as follows. First, process the information that has been collected either limited from the results of collecting activities / experiments as well as the results of observing activities and information gathering activities. Second, creating information collected from nature to add breadth and depth to the information processing that are looking for solutions from a variety of sources that have a different opinion to the contrary.

Competencies developed in the process of associating / managing information are Developing honest, meticulous, disciplined, obedient, hard work, ability to apply procedures and inductive and deductive thinking skills in concluding.

### Communicating

Communicative learning activities are to deliver results of observations, conclusions based on the results of analysis orally, writ-

ten, or other media. Competents developed in communicating stages are developing honest, meticulous, tolerant, systematic thinking skills, expressing opinions briefly and clearly, and developing good and correct language skills.

The observation of students' social skills during the learning process with the scientific approach are as follows.

**Table 3.** Student social skills.

Meeting	Score
1st	2.35
2nd	2.78
3rd	3.00
4th	3.38
5th	3.22
6th	3.46
Average	3.03

The average of students' social skill of 3.03 is in very good category. This is because students are facilitated by the student's worksheet and the media of three-dimensional dynamic electricity. Students' social skills were observed during the learning with the scientific approach is the ability to communicate and cooperative skills. According to the Ministry of Education's theory (2002) as cited by Susiwi (2007), communication means communicate not just deliver the message, but communications with empathy. Empathy, understanding attitudes, and the art of two-way communication need to be developed in the communication skills so that the contents of the message up and accompanied by a good impression that can foster harmonious relationships. Communicating can be through oral or written. For oral communication, the ability to listen and convey ideas orally should be developed. Communicating oral with empathy means the ability to choose words and phrases that are easy to understand by the other person. This skill is very important and needs to be grown in education. Communicating through writing is also a very important thing and has become a necessity of life. Skill pouring ideas through writing that is easily understood by others, is one example of the communication skills of writing. Further, he said that as social beings, in everyday life people will always need and cooperate with other human beings. Cooperative skills are not just "working together" but cooperation is accompanied by mutual understanding, mutual respect, and mutual help. Susiwi (2007) states

that cooperative skills can be developed in all subjects, for example, work on group assignments, field trips, and other forms of activity.

The learning outcomes of the cognitive domain as an indicator of students' academic skills are as follows.

**Table 4.** Academic student skills.

Student ID	Score	Completeness
1	92	Complete
2	72	Complete
3	72	Complete
4	76	Complete
5	64	Incomplete
6	84	Complete
7	92	Complete
8	76	Complete
9	68	Complete
10	88	Complete
11	88	Complete
12	64	Incomplete
13	88	Complete
14	68	Complete
15	88	Complete
16	80	Complete
17	88	Complete
18	64	Incomplete
19	76	Complete
20	64	Incomplete
21	92	Complete
22	68	Complete
23	64	Incomplete
24	72	Complete
25	68	Complete
26	72	Complete
27	68	Complete
Average	76	Complete

The average student's academic of 76 with classical completeness as much as 81%. Implementation of the learning device with a scientific approach to develop a student's academic skills include skills: identifying variables, explaining the relationship variables, formulating hypotheses, designing and conducting experiments.

## CONCLUSION

The observation of lesson plan with a scientific approach by teachers earn an average value of 3.38 are in the very good category, students' social skills amounted to 3.03 are in the very good category, students acquire the academic skills average of 76 are in good category. Thus, it can be concluded that the implementation of learning tools with scientific approach is effective to support the learning activities in physics.

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## REFERENCES

- Agustina, P. and Saputra, A. (2012). Learning Implementation Problems of Life Skills-Based Biology (*Life Skills*) in Indonesia. *Proceeding National Seminar IX*. Surakarta: Biology Education FKIP University of Sebelas Maret (UNS).
- Akinbobola, AO & Afolabi, F. (2010). Constructivist practices through guided discovery approach: The effect on students' cognitive achievement in Nigerian senior secondary school physics. *Eurasian Journal of Physics and Chemistry Education*. 2 (1): 16-25.
- Anwar. (2006). *Life Skills Education: Concepts and Applications*. Bandung: Alfabeta.
- Arikunto, Suharsimi. (2006). *Research Procedure: A Practice Approach*. Jakarta: Rineka Cipta.
- Ibnu, S. (2014). Implementation of Curriculum 2013 In Science Lesson. *Proceedings of the National Seminar: Research, Science Learning, and Curriculum 2013*. Implementation Mataram: PPS Science Education Master program Mataram University.
- Ibrahim, Muslimin. (2003). *Learning Device Development*. Jakarta: Dirjen Dikdasmen Depdiknas.
- Ibrahim, Muslimin. (2005). *Sustainable Assessment: Basic Concepts, Stages of Development and Examples*. Surabaya: Unesa University Press.
- Jufri, A. Wahab. (2010). *Learning and Learning Science*. West Lombok: Arga Puji Press.

- Kemendikbud. (2013). *Teacher Training Content: Implementation of Curriculum 2013*. Jakarta: Kemendikbud.
- Khera, S. & Khosla, S. (2012). A Study Of Core Life Skills Of Adolescents In Relation To Their Self Concept Developed Through Yuva School Life Skills Program. *International Journal of Social Science and Interdisciplinary Research*, Vol.1 Issue 11.
- Machin, A. (2014). Implementation of Scientific Approach, Planting Character and Conservation Learning Materials On Growth . *Indonesian Journal of Science Education*, 3 (1), 28-35.
- Mugambi, MM & Muthui, RK ( 2013 ) . Structural Influence Of Context On Implementation Of Secondary School Life Skills Curriculum In Kajiado County, Kenya. *International Journal of Education and Research*, Vol. 1 No. 3.
- Oladejo, MA, Olosunde, GR , Ojebisi, AO, Isola, OM (2011). Instructional Materials and Students' Academic Achievement in Physics: Some Policy Implications. *European Journal of Humanities and Social Sciences*, Vol. 2, 1.
- Rules Minister of Education and Culture of the Republic of Indonesia Number 81A Year 2013 about Curriculum Implementation .
- Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education*, 93 (3), 223-231.
- Sani, Ridwan Abdullah. ( 2014 ) . *Scientific Learning to Implement Curriculum 2013*. Jakarta: Earth Literacy.
- Sudjana, N., & Rival, A. ( 2013 ) . *Teaching Media (Using and Making)*. Bandung: New Light Algensindo.
- Sukiman. ( 2012 ) . *Learning Media Development*. Yogyakarta: Pustaka Insan Madani.
- Suprihatiningrum, Jamil. ( 2013 ) . *Learning Strategies: Theory and Applications*. Jogjakarta: Ar-Ruzz Media.
- Susiwi. Life Skills ( *Life Skills* ). Bandung: UPI 2007.
- BBE team mone. ( 2012 ) . *Implementation Patterns of Life Skills Education*. Surabaya: SIC.
- Reader Tim Yustisia. ( 2008 ) . *Complete Guide KTSP (KurikulumTingkat Satuan pendidikan )*. Jakarta: Pustaka Yustisia.
- Trianto. ( 2008 ) . *Designing Contextual Learning (Contextual Teaching and Learning) in the Class*. Jakarta: Smart Reader.

# THE PROBLEM SOLVING LEARNING MODEL BY USING VIDEO RECORDING ON EXPERIMENTS OF KINEMATICS AND DYNAMICS TO IMPROVE THE STUDENTS COGNITION AND METACOGNITION

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## ABSTRACT

This research aimed to improve students's cognition and metacognition through kinematics and dynamics of particle experiment assisted by video recording and tracker software analysis. The research used problem solving learning model which developed using R & D method with 4-D steps, they are define, design, develop, and disseminate. The research involved 86 physics education students academic year 2013/2014 at one of the universities in Medan. The research method is quasi-experimental using randomized control group pretest-posttest design. The experimental class used problem solving learning model assisted by video recording and the control class used direct learning model. The cognition data were collected using multiple-choice test and meta-cognition data were collected using essay test. The students's cognition and metacognition improvement characterized by the normalized gain score. The research result show that the use of video recording and tracker software analysis was improve the students' cognition and metacognition in Kinematics and Dynamics topic in moderate category.

## ABSTRAK

Penelitian ini bertujuan untuk meningkatkan kognisi dan metakognisi siswa melalui eksperimen kinematika dan dinamika berbantuan rekaman video dan analisis perangkat lunak pelacak lintasan. Penelitian ini menggunakan pemecahan masalah model pembelajaran yang dikembangkan dengan menggunakan metode R & D dengan langkah-langkah 4-D, yaitu mendefinisikan, mendesain, mengembangkan, dan menyebarkan. Penelitian ini melibatkan 86 mahasiswa pendidikan fisika tahun akademik 2013/2014 di salah satu perguruan tinggi di Medan. Metode penelitian ini adalah kuasi-eksperimental menggunakan kelompok kontrol acak desain *pretest-posttest*. Kelas eksperimen digunakan model pembelajaran pemecahan masalah dibantu oleh rekaman video dan kelas kontrol dengan model pembelajaran langsung. Data kognisi dikumpulkan menggunakan test pilihan ganda dan data meta-kognisi dikumpulkan dengan menggunakan tes esai. Peningkatan kognisi dan metakognisi mahasiswa ditandai dengan skor gain yang dinormalisasi. Hasil penelitian menunjukkan bahwa penggunaan rekaman video dan analisis perangkat lunak pelacak lintasan mampu meningkatkan kognisi dan metakognisi mahasiswa pada topik Kinematika dan Dinamika dalam kategori sedang.

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**Keywords:** problem solving learning model; cognition; metacognition

## INTRODUCTION

Generally, physics learning at classroom, whether for based level to higher level education faced some problems. Learning activity still used traditional method, that is direct

learning model (Selcuk, Caliskan, & Sahin, 2013; Gok & Silay, 2008) and non-contextual (Mariati, 2012). Questions given to students has always struggled with mathematics equations and very rarely associated with contextual issues. This phenomenon led to the development of students's cognition and metacognition about physics problems of less highly trained optimally.

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Physics in higher education should be taught by presenting daily life problems to practice their higher order thinking skills, such as cognition and metacognition. Therefore, managing the learning activity to fulfill the principles of better teaching and learning in higher education such as students centered learning, learning by doing, autonomous learning, as well as cooperative learning. In accordance to the principles, the learning activity is expected not only focused on lecturer activities but moreover the students activities in their learning process, especially in General Physics subject.

General Physics is one of compulsory subject for physics teacher candidate in higher education. The subject is given at the first semester since the subject is a pre requirement to the next semester program. This subject is the basis of the development of the engineering, design, planning, and technology. Therefore, the subject has an important role in various parts of live and and indirectly build the pattern of human thought. Unfortunately, General Physics is one of subject that considered as a difficult subject by the students, whereas it is a basic and essential subject that should be mastered by the students. If the student does not master it well, then it is very possible for them to have difficulty attended the lectures in the next semester.

Based on observation result in one of higher education in Medan, it is found that the General Physics learning result is still low. This is because more half of student is less interest in learning Physics and they considered it as a difficult subject. Gok & Silay (2008) stated that learning result of Physics is lower than other subject because it considered as one of difficult subject by student, so the students less interest in learning Physics. It is very common that sains, especially Physics, is considered as a difficult and not so favored subject (Setiawan, 2009). Based on the results of several studies, there are several reasons why physics is not so favored, among others: it is need complicated mathematics (AAPT, 2009); to many material and need laboratory activity (Sheppard & Robin, 2009; K. Heller, 1999); and often take misconception (Anderson & Nashon, 2006). The reasons also occurred in this research subject. The students do not seem enthusiastic when already up on materials related to a sufficiently complex mathematical formula; the material is quite dense and they could not connect them with other physics concepts; and considers laboratory experiments do not support the con-

cept mastery

The prelemenary study show that General Physics learning results were not accordance with the standard yet. The learning process was not fully support the development of the students's cognitive such as skills to memorize, to comprehend, to apply, to analyse, to evaluate, as well as to creat, and their metacognition. Importances of cognition and metacognition development in learning activity have been reported by previous researcher (Kipnis & Hofstein, 2007; Weinert & Kluwe, 1987). According to Kipnis & Hofstein (2007), metacognition is an important component in science since metacognition processes gives meaningful learning, provides the student to learn the benefit of science in a future, and supports the students to learn autonomous. The idea also supported by Weinert & Kluwe (1987) who suggested that Higher Education should become ideal place for meta-cognition development. It is because there is so many learning of self-awareness in continuing the learning process. In Higher Education, student has repeatedly changes to monitor and to manage their cognition, has more meta-cognition knowledge, as well as has more opportunity to achieve meta-cognition skill.

Cognition considers as what is known and taught by someone or it does include skill that related to thinking process (Matlin, 2009; Anderson & Krathwohl, 2001; Costa, 1985). Components in cognition field consist of memory, comprehension, application, analysis, evaluation, and creation (Anderson & Kratwohl, 2001). Meta-cognition is a knowledge, awareness, and control of cognition process (Matlin, 2009; Anderson & Kartwohl, 2001; Schraw & Moshman, 1995). Schraw & Moshman (1995) divided meta-cognition into two components, knowledge and skill of meta-cognition. Meta-cognition knowledge defined as knowledge and comprehension in thinking process. Meta-cognition skill defined as control in thinking process. Three components of meta-cognition knowledge are declaration, procedural, and conditional. Four components of meta-cognition skill are prediction, design, monitor and evaluation.

Students cognition and meta-cognition can be developed through problem solving learning. Tan (2004) and Foshay & Kirkley (2003) said that problem solving model can influence student's cognition. More over Foshay & Kirkley (2003) said that with learning model of problem solving, cognition can be developed by using presented the problem, find solution,



and evaluation. Hollingworth & McLoughlin (2002) found that meta-cognition can be improved in a learning environment of problem solving and problem solving learning (Winert & Kluwe, 1987).

In this research Physics learning model is set based on problem solving environment in order to increase students cognition and meta-cognition. Problem solving process in this context is done by experiment and contextual problem solving. Experiment based on problem solving was set to train the students in making prediction, answering question, setting design, doing exploration, doing measurement, analyzing, and making conclusion (K. Heller & P. Heller, 1999). The problem solving steps in the experiment guide the students when they doing experiment which assisted by video using software tracker. This software functions as mathematics program of the project in video and cut up object position that move every time. The benefit of the video usage to experiment activity such as 1) to investigate the problem of real life situation, 2) can be accessed anytime, 3) present moving things in two dimension, and 4) can be varied easily so that it help the student to construct and develop comprehension concept (Teese, 2007; Zollman, 2001). Therefore, the aim of the research is to develop the Physics learning model based on problem solving to increase the student cognition and meta-cognition.

## METHOD

In order to develop Physics learning model based on problem solving, method of R and D through four steps that is define, design, develop, and disseminate was used (Thiagarajan, D. Samuel, & M. Semmel, 19974). Procedure of research and development model based on problem solving in definition stage (define) is conducted through need analysis by collecting various information related to the product that will develop. Collecting various informations was conducted by preliminary study through literature and field study. The results of literature and field study were used as a material to design a set of preliminary product that is physics learning model and learning equipment to support the model. The products are 1) guidance of learning management; 2) syllabus and lesson plan based on problem solving; 3) student work sheet; 4) test (cognition and meta-cognition test). Product development conducted with expert validation, limited try out test, and wider

scale test.

The method of limited try out test used in this research is quasi experiment with randomize control group pretest-posttest design. The samples are 86 physics teacher candidate consists of 47 students in experiment group and 39 students in control group. The cognition test is multiple choices which consist of 20 items of kinematics particle topic and 20 items of dynamic particle topic. The test includes indicators in cognition domain they are memory, comprehension, application, analysis, evaluation and creation (Anderson & Krathwohl, 2001). Test meta-cognition is essay test which consist of 8 items of kinematic particle topic and 8 item of dynamic particle topic. The indicators of meta-cognition test are prediction, plan, monitor, evaluate, declaration, procedural and conditional (Schraw & Moshman, 1995).

Limited try out conducted to see the effectiveness implementation of physics learning model based on problem solving towards cognition and meta-cognition of the students. Activeness implementation of problem solving model to increase cognition and meta-cognition was determined based on mean score of gain that normalized, N-gain. The N-gain can be classified as follows: 1) if N-gain > 70%, so N-gain is in high category; 2) if  $30\% \leq \text{N-gain} \leq 70\%$ , so that N-gain is in moderate category; and 3) if N-gain < 0%, so N-gain is in low category (Hake & Richard, 2002).

Syntax of problem solving learning model was adapted from Arends (2004) with phases are 1) oriented the student to problem, 2) organized the student to learn, 3) guided group and individual investigation, 4) develop and presented investigation result, 5) strengthened and reflection syntax of conventional learning model started from introduction, main activity and closing.

Meta-cognition knowledge can develop through syntax of problem solving learning because when the problem is present, the student will be guided to realize what they already know and what they should know. Student demanded to be able to relate between one to other concept and connected those concepts with their previous knowledge. Procedural knowledge can be developed because in conducting experiment, student should know about what the procedure of problem solving. Conditional knowledge can be developed because student should know the reason why they use the problem solving strategy and know what is the right and appropriate strategy to solve the problem.

Meta-cognition skill also can be developed through problem solving, because student demanded to make prediction before conducted next investigation, student also demanded to plan their own experiment because in student work sheet there is no work procedure. In planning experiment, students prepare what will they do, choose data or information that given, and choose the right and efficient mean from available experiment equipments. By designing their own experiment, student will be challenging and motivating to collect information from various sources to solve the problem that they faced. Students will have a competent in monitoring because they demand to do correction of their investigation phases whether it accordance to the plan that they made before or not. Students will also have a competent in evaluation because they were demanded to assess whether analysis results are suitable with the theory and to assess the procedure accuracy that used and made conclusion after doing investigation.

## RESULTS AND DISCUSSION

Based on the expert assessment, generally the content and construction of the test is fulfilling criteria to measure the students' cognition and meta-cognition.

Effectiveness of *problem solving* learning model in increasing student' cognition

Effectiveness test of problem solving learning model in increasing students' cognition is descibed using N-gain percentage of kinematic and dynamic particle topics. Results of normality test, homogeneity test, and mean different test of N-gain percentage of control and experiment group in kinematic and dynamic particle topic are shown in Table 1. Based on Table 1 it shows that N-gain percentage of student cognition of experiment and control group is normal

distribution and homogeny variant. The N-gain percentage between two groups by using different test (t-test) shows that implementation of physics learning model based problem solving can increase significantly the student cognition in kinematic and dynamic particle topic.

Based on Table 1, the students' cognition achieved by experiment group is higher than control group. It can be concluded that implementation of learning model of problem solving assisted video in kinematic and dynamic particle topic can be more effective to increase the students' cognition compare to usage of conventional learning model.

N-gain percentage of cognition which explains each indicator between experiment and control group is shown in Figure 1. N-gain percentage of cognition is lower for experiment and control group occur in cognition domian is for creating things. It is because creating work has a high difficult level compared to other cognition aspects (memory, comprehension, application, analysis, and evaluation)

N-gain of percentage in memory and comprehension aspects of experiment group is higher than other cognition aspect. It is because in problem solving phases, when data of experiment in form of video recording were analyzed using software tracker, student can more memorize and understand. The students have opprtunity to conduct investigation through experiment autonomy. The learning model support the students to strenghthen their memory and comprehension in constructing and developing their concepts.

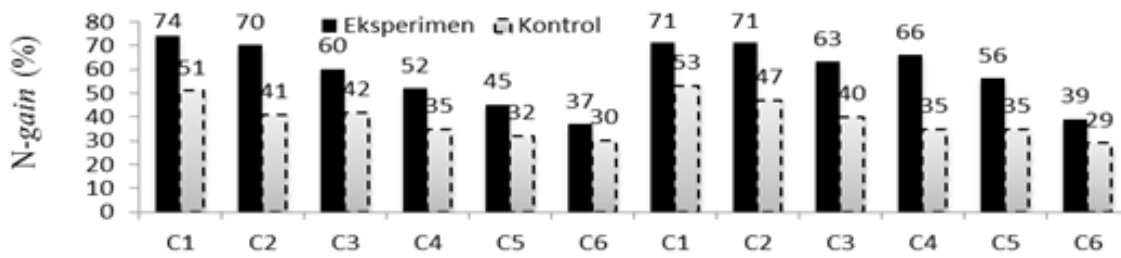
Effectiveness of problem solving learning model in increasing students' meta-cognition.

Result of normality test, homogeneity test and mean different test of *N-gain* percentage between experiment and control group in kinematic and dynamic particle topics is shown at Table 2. The N-gain percentage of student

**Table 1.** Cognition result achieved by both groups.

Topic	Experiment group				Control group				Varians % N-gain <sub>Exp</sub> with % N-gain <sub>Cont</sub>	p
	Mean		N-gain (%)	Cat-egory	Mean		N-gain (%)	Cat-egory		
	Pre test	Post test			Pre test	Post test				
Kine-matics	21.91	65.21	56	moderate	26.67	54.74	38	moderate	homogen	0.000 (significant)
Dynam-ics	23.72	70.85	62	moderate	27.31	55.38	39	moderate	homogen	0.000 (significant)

Maximum score: 100



**Kinematics**

**Dynamics**

**Figure 1.** Comparison of cognition *N-gain* percentage on Kinematic and Dynamic particle topics based on experiment and control group indicator. The indicators: C1 = memory, C2 = comprehension, C3 = application, C4 = analysis, C5 = evaluation, C6 = creation.

**Table 2.** Results of meta-cognition achieved by both group

Topic	Experiment group				Control group				Varians % N-gain <sub>Exp</sub> with % N-gain <sub>Cont</sub>	p
	Mean		N-gain (%)	Cat-egory	Mean		N-gain (%)	Cat-egory		
	Pre test	Post test			Pre test	Post test				
Kinemat-ics	10.37	65.89	62	moder-ate	12.10	52.88	46	moder-ate	homogen	0.000 (signifi-cant)
Dynamics	9.38	70.94	68	moder-ate	10.90	61.06	56	moder-ate	homogen	0.000 (signifi-cant)

Maximum score: 100

meta-cognition at Kinematic and Dynamic particle topics, both groups has normal distribution and the variant is homogen. Different significant of *N-gain* percentage increase meta-cognition of experiment and control group used different test. Results of different test show that implementation of learning model based on problem solving more effective to increase students' meta-cognition significantly.

Based on Table 2, it is shown that meta-cognition achievement gain by experiment group is higher than control group. It can be concluded that implementation of problem solving learning model using video recording analysis at Kinematic and Dynamic topics is more effective to increase students' meta-cognition compared with usage of conventional learning model. The percentage of *N-gain* meta-cognition explains each of indicators between experiment and control group as shown in Table 3.

*N-gain* percentage of meta-cognition achieved by experiment group is higher if compared to control group. It is because in problem solving phases through experiment, student demanded to be able to predict the solution of the problem, to plan what will they do, to do investigation procedural phase, to monitor, as

well as to evaluate the process. When the student prepare the plan of the experiment, they were challenged and pushed to think about every procedural phase and goal from each phases. So that, the students were trained to find out various informations and discuss them with their peer about their ideas to solve the problem. It is accordance with Kipnis & Hofstein (2007) that by arranging experiment plan students will be trained to develop their meta-cognition in making a planning and they also trained to think about every procedural as well as goal phases from each phase.

Research result shows that through implementation of problem solving learning model assisted by video recording can increase student cognition of memory, comprehension, application, analysis, evaluation, and creation. The video recording analysis using software tracker, where the analysis results are graph of position toward time and speed toward time, provide an opportunity to the student to interpret the graph and continued analysis. In this process the students try to apply their previous concepts and to evaluate the results, so that they can construct their knowledge, excavate the ideas related to the essential concepts. By

**Table 3.** Percentage of meta-cognition indicators of experiment and control group.

Meta-cognition Indicators	N-gain of Experiment Group (%)				N-gain of Control Group (%)			
	Kinematics	Criteria	Dynamics	Criteria	Kinematics	Criteria	Dynamics	Criteria
Declaration	59	moderate	68	moderate	53	moderate	67	moderate
Procedural	71	high	73	high	47	moderate	54	moderate
Conditional	70	moderate	65	moderate	44	moderate	64	moderate
Prediction	56	moderate	70	moderate	45	moderate	56	moderate
Planning	72	high	74	high	46	moderate	50	moderate
Monitoring	55	moderate	67	moderate	44	moderate	57	moderate
Evaluating	52	moderate	65	moderate	38	moderate	48	moderate

doing this activity the students ideas will appear and develop through process of continued thinking.

Problem solving learning using video recording shows positif impact in increasing the student cognition and meta-cognition. It is because through this model the students have a chance to conduct the investigation in solving the problem through experiment. The experiment using video recording analysis was done as follows. First, students were given opportunity to make prediction about solution of the problem they faced before conducting continued investigation through experiment. The prediction is supported by appropriate and deep physics concepts. Secondly, they try to answer the questions before conduct continued and appropriate investigation with problem that solved used appropriate physics concepts. The question intention to provide an opportunity to the student in exploring theory to support the investigation. Thirdly, giving opportunity to the students to choose the equipment and material. Fourth, students conduct the plan of the experiment, equipment set up, determine the experiment steps, determine the variables measured, making the observation table. By gaining the data of the experiment, the students will have a chance to investigate the problem and to arrange the plan of experiment so that they can achieve knowledge and new experiences from their experiment results. Fifth, variables measurement is conducted according to what they plan previously. The variables is not written in the student worksheet to give freedom to the students to practice their ability to solve

problem so that their ability in predicting and analyzing will be sharpen. Measurement in this experiment is conduct through video recording using software tracker. Sixth, the data of video recording were analyze using software tracker. The analysis results are graph of position toward time and speed toward time. Seventh, the students made appropriate conclusion with analysis results and then compared them with their previous prediction and answer of questions.

The research results are accordance to previous findings that through problem solving can increase concept mastery (Duch, Groh, & Allen, 2001; Akinoglu & Tandogan, 2007). Giving the problem will raise the students's curiosity and motivation to solve the problem so their concept mastery will increase as well (Fogarty, 1997). The finding is supported also by Tan (2003) who said that learning through problem solving can increase transfer concept to new situation, integration concept, intrinsic learning interest, and learning skill. This learning helps students to construct their knowledge and continued reasoning skill.

Problem solving learning using video recording demanded the students to evaluate the results whether they were appropriate to the theory as well as to consider the accuracy of analysis results. When the experiment was recording using video equipment and was analyzing using software tracker, the students can repeat the experiment if they make mistaken. While the students analyze those data, they can collect good part of the experiment results so it can help student conduct accurate inves-

tigation as well as analyze and give deep comprehension to them.

As already explained in the previous researches that the advantage of video usage in experiment activity are 1) can be used to investigate problem of real life situation with contextual concept; 2) freely accessed, picture per frame, and can be slowed down; 3) can be cutted and classified the part that will be used; 4) presenting moving thing in two dimension; 5) evaluation from this activity has potential to offer university level instructor and students the better way to visualize, investigate, analyze, and comprehend various topics in physics; 6) the video recording can be analyzed easily so it can help the students to construct and develop their comprehension (Teseo, 2007; Wagner, Altherr, Eckert, & Jodl, 2006; Zollman, 2001; Escalada & Zollman, 1997).

Based on analysis above, it can be conclude that through problem solving learning model, the students' cognition and meta-cognition can be build. It is supported by Foshay & Kirkey (2003) who said that problem solving model can influence learner cognition. They also stated that through problem solving learning model, students' cognitive that can be develop are: 1) explore knowledge that accordance to context, 2) find a solution of problem solving and develop plan to gain the goal, 3) apply the solution include doing what they plan and evaluate it. Tan (2004) noted that problem solving in learning process, plan of problem solution and the phase help learners to develop cognitive relation combination. By collecting data and information, learners need to apply analytic thinking ability, to compare and to classify the data. The learners will determine learning strategy, compare and share it to their peers to solve the problem. Awareness of self-thinking to direct, to compare, and to share learning strategy shows that the learners are involved in the learning activities. The idea is supported by Hollingword & McLoughlin (2002) who stated that meta-cognition ability, can guide the students to plan learning environment and choose strategy to fixed cognition performance in a future as well as to increase their learning results, especially their memorize ability and comprehension. Anderson & Nashon (2006) found that meta-cognition had by the students can increase learning capacity, support, and influence the students to construct their knowledge.

## CONCLUSION

It have been develop a physic learning model that suitable with physics characteristic, named problem solving learning model by using video recording. Based on limited try out test of model development in general physic learning, it can be concluded that implementation of problem solving learning model significantly resulted N-gain of cognition and meta-cognition in Kinematic and Dynamic particle topic in low category. The results show that implementation of problem solving learning model by using video recording is more effective to increase students' cognition and meta-cognition capability.

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## REFERENCES

- AAPT. 2009. "Building a stronger foundation in the knowledge and understanding of science, American Association of Physics Teacher".
- Akinoglu, O. & Tandogan, O. (2007). Effects of Problem-Based Active Learning in Science Education on Students' Academic Achievement, Attitude and Concept Learning. *Eurasia Journal of Mathematics, Science & Technologi Education*, 3 (1), 71-81.
- Anderson, L. W. & Krathwohl, D. R. (eds). (2001). *A Taxonomy for Learning Teaching and Assessing*. A Revision of Bloom's Taxonomy of education Objectives. New York: Addison Wesley.
- Anderson, D. & Nashon, S. (2006). Predators of Knowledge Construction: Interpreting Students' Metacognition in an Amusement Park Physics Program. *Wiley InterScience*.
- Arends, R. I. (2004). *Learning to Teach*. 5<sup>th</sup> Ed. Boston: McGraw Hill.
- Costa, A.L. (ed). (1985). *Developing Minds, A Resource Book for Teaching Thinking*. Alexandria: ASCD.
- Duch, B. J., Groh, S. E., & Allen, D. E. (2001). *The Power of Problem-based Learning*. Virginia: Stylus Publishing, LLC.
- Escalada, L., & Zollman, D. A., (1997). An Investigation on the Effects of Using Interactive Digital Video in a Physics Classroom on Student Learning and Attitudes. *Journal of Research in Science Teaching*. 34, (5). 467-489.
- Fogarty, R. (1997). *Problem-based Learning and Multiple Intelligences Classroom*, Melbourne: Hawker Brownlow Education.
- Foshay, R. & Kirkley, J. (2003). *Principles for Teach-*

- ing Problem Solving. PLATO Learning, Inc.
- Gok, T. & Silay, I. (2008). Effects of Problem-Solving Strategies Teaching on The Problem Solving Attitudes of Cooperative Learning Groups in Physics Education. *Journal of Theory and Practice in Education*. 4 (2): 253-266.
- Hake & Richard, R. (2002). *Relationship of Individual Student Normalized Learning Gains in Mechanics with Gender, High-School Physics, and Pretest Scores on Mathematics and Spatial Visualization*.
- Heller, K., & Heller, P. (1999). *Problem-Solving Labs*. Introductory Physics I Mechanics. Cooperative Group Problem-Solving in Physics.
- Hollingworth, R. & McLoughlin. (2002). *The Development of Metacognitive Skills among First Year Science Student*.
- Kipnis, M., & Hofstein, A. (2007). The Inquiry Laboratory as a Source for Development of Metacognitive Skills. *International Journal of Science and Mathematics Education*.
- Mariati, P.S. (2012). Pengembangan Model Pembelajaran Fisika Berbasis *Problem Solving* untuk Meningkatkan Kemampuan Metakognisi dan Pemahaman Konsep Mahasiswa, *Jurnal Pendidikan Fisika Indonesia (JPFI)*, 8(2), 152-160.
- Matlin, M. E. (2009). *Cognitive Psychology*. Seventh Edition. International Student Version. Jhon Wiley and Sons, Inc.
- Schraw, G. & Moshman, D. (1995). *Metacognitive Theories*. Educational Psychology, Department of Educational Psychology Papers and Publications.
- Sheppard, K. & Robbins, D.M. 2009. The First Physics First Movement, 1880-1920. *The Physics Teacher*, 47, 46-50.
- Setiawan, A. (2009). *Pemanfaatan Teknologi Informasi dan Komunikasi (TIK) dalam Pembelajaran Sains*. Materi Workshop dalam Kegiatan Pengabdian Masyarakat SPs UPI, Rabu 29 Juli 2009.
- Selcuk, Caliskan, & Şahin, 2013, A Comparison of Achievement in Problem-Based, Strategic and Traditional Learning Classes in Physics, *International Journal on New Trends in Education and Their Implications (Ijonte)*, 4(1), 154-164.
- Tan, O. S. (2004). *Enhancing Thinking Problem Based Learning Approached*. Singapura: Thomson.
- Tan, O. S. (2003). *Problem-based Learning Innovation*. Singapore: Thomson Learning.
- Teese, R. (2007). *Video Analysis - A Multimedia Tool for Homework and Class Assignments*. 12<sup>th</sup> International Conference on Multimedia in Physics Teaching and Learning, 13-15 September 2007, Wroclaw, Poland.
- Thiagarajan, S., Semmel, D. S., & Semmel, M. (1974). *Instructional Development for Training Teachers of Exceptional Children*. Source Book. Bloominton: Center for Innovation on Teaching the Handicapped.
- Wagner A., Altherr, S., Eckert, B., and Jodl, H. J. (2006). Multimedia in physics education: a video for the quantitative analysis of the centrifugal force and the Coriolis force. *Eur. J. Phys.* 27 (2006) L27–L30.
- Weinert, F.E., & Kluwe, R.E. (1987). *Metacognition, Motivation, and Understanding*. London: Lawrence Erlbaum Associates.
- Zollman, D. A. (2001). *Modeling Real World Events and Video Data Collection*.