

# THE USE OF INTERACTIVE MULTIMEDIA (MACROMEDIA FLASH) TO INCREASE CREATIVE THINKING ABILITY OF STUDENTS IN BASIC PHYSICS SUBJECT

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## ABSTRACT

Students were intellectuals who should have the ability to think critically, one of which is the creative thinking skills. However, the students' limited ability in basic physics as well as the limitations of using a variety of multimedia resulted in basic physics final exam result was lower than 6 on average from maximum value of 10. This leads to the lower creative thinking skills of students in basic physics. This research was a Quasi Experiment research on students in the first semester of academic year 2014/2015 which amounted to 38 people. This research was expected to increase creative thinking skills as well as lecturers and students activities. Data obtained from this study was the data of creative thinking skills of students and data on the observation of activity of lecturers and students. The data were analysed by using formula percentage of completeness of learning outcomes, gain index and statistical t-test. Based on the results of data analysis it is showed that the use of interactive multimedia (Macromedia Flash) can improve creative thinking skills of students.

## ABSTRAK

Mahasiswa adalah kaum intelektual yang seharusnya memiliki kemampuan berpikir tingkat tinggi, yang salah satunya adalah keterampilan berpikir kreatif. Namun keterbatasan kemampuan dasar fisika mahasiswa serta keterbatasan penggunaan berbagai multimedia mengakibatkan hasil ujian final fisika dasar mereka rata-rata dibawah angka kriteria ketuntasan minimum. Hal ini mengindikasikan bahwa keterampilan berpikir kreatif mahasiswa pada mata kuliah fisika dasar rendah. Penelitian ini adalah penelitian Quasi Experiment Melalui penelitian ini diharapkan akan dapat meningkatkan keterampilan berpikir kreatif serta aktivitas dosen dan mahasiswa. Data yang diperoleh dari hasil penelitian ini adalah data keterampilan berpikir kreatif mahasiswa dan data hasil observasi aktivitas dosen dan mahasiswa. Setelah semua data terkumpul dianalisis dengan menggunakan rumus persentasi ketuntasan hasil belajar, indek gain dan statistik uji-t. Berdasarkan hasil analisis data diperoleh bahwa penggunaan multimedia interaktif (Macromedia Flash) dapat meningkatkan keterampilan berpikir kreatif mahasiswa.

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**Keywords:** Creative thinking skills; Interactive multimedia (Macromedia Flash)

## INTRODUCTION

Basic physics courses in physical education courses are the foundation for students to face and study other subjects in the following semester; therefore student of physics education is very important to thoroughly master the basic physics. The students' basic capabilities

related to mastery of concepts of physics is very important. Makrus and Hadiprayitno (2012) expressed his opinion about the science that science is not just made up of a collection of knowledge isolated from one another, rather than a collection of knowledge organized systematically. This opinion of Hadiprayitno and Makrus reinforces that the mastery of basic physics perfectly as a part of science plays an important role. Nevertheless, the results of experience as a lecturer of basic physics course

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during the last 3 years in the study of physics education, shows that the ability of the average student is still relatively low. It can be seen from the midterms and final exams results especially those of basic physics course which gain under 6 on average from maximum value of 10 and based on data from the service center KHS and KRS students information obtained that 55% of first semester students reprogram the subjects of Physics essentially is C or D.

Based on these findings followed by interview sessions, it is found that the lack of mastery of the physics is influenced by their habit while in high school that while they were studying physics they just applying physics equation without understanding the physics concept underlying. This is in line with that expressed by Sabella & Redish (2007) that one of the causes of low mastery of physics is that students learn only the surface pattern. Furthermore, Kristianingsih, Sukiswo & Khanafiah (2010) also says that due to the teachers are prone to give more lectures or simply delivering product, resulted the poorly trained students in developing the ability of thinking in order to develop application concept that has been learned in real life. Additionally, the learning activity should not be done only one way though the subject of the learners are the students. This is because the process of learning itself is a process that emphasizes providing direct experience to develop the competencies so that students are willing to explore and understand the universe around scientifically. Based on those direct experiences, all students' learning activities will be monitored by the lecturer.

In line with this statement, Subali, Sopyan, & Ellianawati (2015) argued that "the activity of the students is a real phenomenon that is evident in students and can be observed as well as be measured by students, in this case the most involved is lecturer. Based on this study, an improvement learning program was made in order to improve student's thinking skills. The improvement is important because physics is not a science which can only rely on mastery of concepts or rote alone. Thus, students should be able to understand a concept by relying with their thinking ability. The physics lesson is a lesson that requires learners more actively involved in classroom. This is in line with what was said by Yerigan (2008), which is active learning will be able to increase the level of interaction between students and higher level thinking.

Many of solutions can be performed by

a lecturer to create learning method that able to attract students, including the use of interactive multimedia (Macromedia Flash). Wahyudin, Sutikno, & Isa (2010) stated that interactive multimedia is a multimedia that allows the users to make an implementation and to receive feedback. Interactive multimedia with Macromedia Flash is one form of media that can be used to achieve the learning objectives. Through the medium, the students can be invited to view an animation of the concept that is being delivered. In connection with the use of interactive multimedia, other researcher has conducted similar research, Wiyono, Liliarsari, & Paulus (2012) with the title of his research "model-based interactive multimedia learning styles to improve the comprehension of the concept of introduction of solid-state physics". They concluded that the use of interactive multimedia-based learning style is more effective than conventional learning in increasing mastery of the concept of introduction to solid-state physics.

Arsyad (2007), gave his opinion regard to the learning media that can be characterized as follows: 1. Fixative feature, which describes the media's ability to record, store, preserve, and reconstruct an event or object; 2. Manipulative feature, which is media's ability to transform an object, event or process in addressing the problem of space and time; 3. Distributive feature, which describes the media's ability of transporting object or event through space, and simultaneously the incident served to a large number of students, in various places, with relatively same stimulus experience about the event.

Sadiman (2007) revealed that "media characteristics in terms of economic, target scope to be covered, and ease of control by the user. Characteristics of the media can also be seen by its ability to arouse entire sensory organs". In this case, knowledge of the characteristics of the medium of learning is very important for the grouping and selection of media, and can be adapted to the specific learning situation. Furthermore Wiyono, Liliarsari, & Paulus (2012) give their opinion regard to the use of interactive multimedia, namely interactive multimedia in teaching physics will greatly help students in understanding the concepts that are abstract. Therefore, it would be a very nice synergy to collaborate the appearance of interactive multimedia and continued with little investigation via existing practical equipment to enhance the creative thinking skills of students.

This is because the skills of creative thinking are one's ability to high level thinking skills and included various activities of process skills. According to Marnita (2013), high-level thinking skills such as self-process skills in students are a talent that should be developed in accordance with the nature of science teaching. As dictated by Chabalengula, Mumba & Mbewe (2012), there are two main abilities in thinking skills such as process skills, which are fundamental skills and integrity skills.

Furthermore Liliasari (2000) mentions that the thinking skills is one of the necessary intellectual potential in many aspects of daily life of students. In this case Hassoubah (2002) stated that creative thinking ability is a process that aims to make sensible decisions about what is believed to be done. Furthermore Munandar (2009), also revealed that the skills of creative thinking consists of several indicators, namely (1) thinking smoothly (in which there are an act of generating many ideas that are relevant, smooth current of thinking, and always think that the answer of a problem is always more than one, (2) thinking flexibly (in which varied ideas/answers/questions were generated, toward a different idea, and is able to change the old-fashioned approach or thought), and (3) thinking in detail development, embellishment, and having an idea, breaking down the problems into details, and expand an idea). Learning process using Macromedia Flash and multimedia coupled with the implementation of a simple lab works, will make the students able to find the concept better, and will be able to generalize any findings into the example in the vicinity. Furthermore, Macromedia Flash multimedia animation also invited students to be directly involved in the process of observation through Macromedia Flash multimedia, followed by testing using simple equipment. These steps hopefully will be contribute to creative thinking construction of the students. Therefore, this study aims to determine whether the use of interactive multimedia (Macromedia Flash) can improve students' creative thinking skills in basic physics course.

**METHOD**

This research was conducted in the classroom of Physics Education Department, Faculty of Pedagogy and Education Almuslim University Bireuen districts of Aceh province. Samples in this study were 38 students of the first semester of academic year 2014/2015.

This study was conducted using Quasi experiment with quantitative approach. A quantitative approach was conducted to test the hypothesis by using some statistical equations corresponding to the data obtained in the field. Quasi experiment was chosen because it is difficult to obtain a control group. According to Sugiono (2009) if the researcher has chosen quasi experiment, the researchers need to do a pre-test as much as four times in order to obtain stability and circumstances of the group prior to treatment.

The data obtained in this study are student learning outcomes data in the form of creative thinking skills, as measured by using the items creative thinking skills. The data were collected from paper documentation and test. The data that have been obtained subsequently processed using several statistical equations. To determine the thoroughness of students' learning outcomes in the form of creative thinking skills in using equation percentage of completeness as has been dictated by Trianto (2011), namely:

$$p = (\text{number of students who pass}) / (\text{total number of students}) \times 100\%$$

From equation percentage of completeness described above, it is known that each student is said to be complete in learning (individual completeness) if the correct answer  $\geq 65\%$ , and a class is said to be complete in learning (classical completeness) if there are  $\geq 85\%$  of students who has completed the study in a class (MONE).

As for knowing the increase in creative thinking skills Meltzer gain index equation (2002), as follows:

$$\text{Gain Index} = (\text{post test} - \text{pre test}) / (\text{maximum score} - \text{pre test})$$

**Table 1.** Gain Index Criteria

Gain Index	Category
$g \leq 0,3$	Low
$0,3 < g \leq 0,7$	Moderate
$0,70 < g \leq 1,00$	High

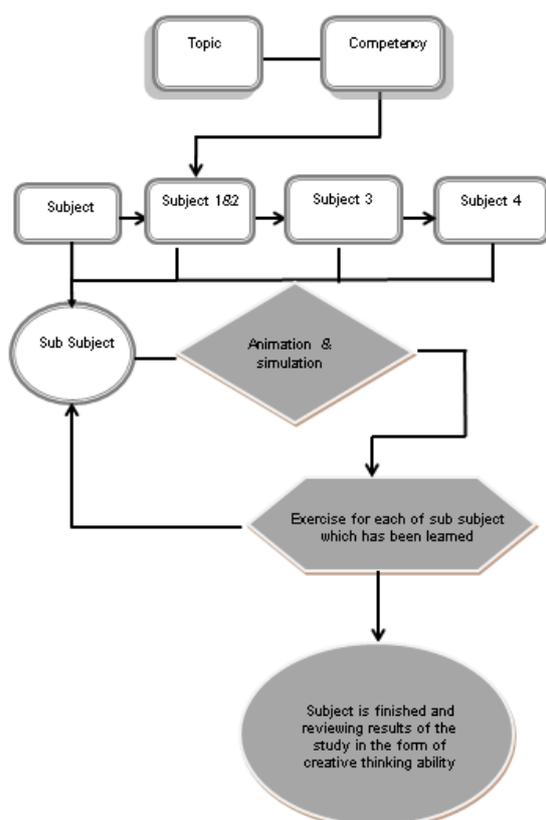
Furthermore, hypothesis testing was done by using t-test statistics dictated by Arikunto (2002), as follows:

$$t = \frac{Md}{\sqrt{\frac{\sum x^2 d}{N(N-1)}}}$$

## RESULTS AND DISCUSSION

### Research results

The study was conducted on subjects Physics, especially on the topic of motion. Prior to the discussion of the findings in this study, the following is a flowchart of specific material that has given treatment in the form of interactive multimedia.



**Figure 1.** The form of flowchart of the material

Before the data of this study are presented in the form of processed data, the researchers have tested the instrument on first semester students of Mathematic education program, Faculty of Pedagogy and Education that had been taking basic physics course. The calculations of the test results include validity, reliability, level of difficulty, and distinguishing features. The result of the calculation reliability of essays by using the formula has the alpha reliability coefficient of 0.66, which means that the reliability coefficient has high reliability. While the results of the calculation of validity of 13 items about the creative thinking skills, 7 of which have high validity criteria, 3 problems which have sufficient criteria, one matter of which have the low criteria and two questions of which have very low criteria. Further calcula-

tions about the difficulty level, 11 of which had moderate criteria, one matter of which have easy criteria, and 1 had a difficult criterion. Calculation of distinguishing features, 10 questions of which have good category, two problems of which have bad category, one question has sufficient categories. Based on test results, the writer decided that 3 out of 13 questions were decided to be discarded and three problems were decided suitable to be used as questions for assessing creative thinking skills.

Based on the results of the initial test results of data processing and final tests that have been done then the whole purpose of this research has been achieved. The general descriptions of the results that have been achieved are as follows:

**Table 2.** General Overview of Research Results on First Semester Students of Physics Education Program on Motion Subject

Value	Pre-test	Post-test
Highest	66.00	97.00
Lowest	20.00	52.00
Mean	29.21	71.00
Variance	24.45	92.34
Standard deviation	4.94	9.60

### Analysis of Creative Thinking Skills completeness

The research principle conducted on students of the first semester, particularly on the motion subject of matter, as a basic step to improve students creative thinking. It is done since the basic ability is still low, then for subsequent materials in the following semester, students will find it hard to master physics that correspond to physical education course curriculum. Based on this fact the analysis of creative thinking skills completeness of students were performed, which standardize the completeness refers to the standards stipulated by the Ministry of National Education that learners are considered complete on an individual basis if the score obtained is over 65% of the determined maximum score. The classical completeness is achieved if 85% of the students are able to achieve score above 65%.

The analysis result of pre-test and post-tests shows that the pre-test or initial test, student who achieve complete category is only one student, while the rest have not yet reached complete category. The result indicate that while in junior high school and high

**Table 3.** Level of Students Creative Thinking Skills in Motion Subject

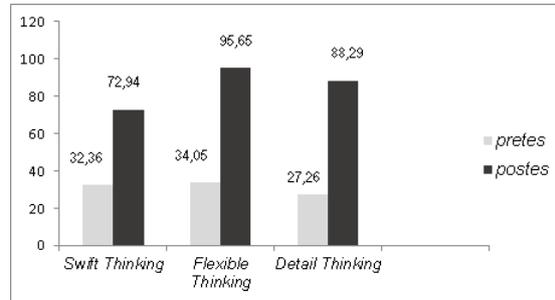
No.	Category	Pretest		Post-test	
		Number of Students	Percentage	Number of Students	Percentage
1	Pass	1	1%	32	93,61%
2	Fail	34	99%	3	6,39%
Total		35	100%	35	100%

school, the students studied physics only on the surface pattern so that mastery of physics is still very low. This is consistent with what has been revealed by Sabella & Redish (2007) who said that one of the causes of weak mastery of physics is that students learn only the surface pattern. Here is the percentage of students at the level of completeness of pre-test and post-tests.

The Table 3 shows that because previously the student in high school studied physics only on the surface pattern, the students were only invited to learn conceptually without involving them in a scientific investigation, the results obtained from the pre-test showed the students' lack of basic knowledge in physics, especially on the concept of motion. It can be seen from the test results that the pre-test showed only 1% of students who completed the test while on post-tests there are 93.61% or 32 students who completed the test or possessed the creative thinking skills ability. This significant difference shows that learning by using interactive multimedia (Macromedia Flash) is further coupled with practical implementation by using a few simple tools provide significant impact for first semester student of physical education program.

The impact can be seen from the completion of the indicators of learning, especially in the form of creative thinking skills. The indicator of creative thinking skills is swift thinking, supple thinking (flexible), and detailed thinking (elaboration). Overall, it can be seen that the average student 's creative thinking skills are higher on the post-test or the final test compared to pre-test or initial tests. The table below illustrates the average level of creative thinking skills of students from each of the indicators of pre-test and post-test.

The graph above is an illustration of average achievement of students' creative thinking skills, which shows that the average achievement indicators were better in post-test compared with pre-test (Figure 2).

**Figure 2.** Average of Student's Creative Thinking Levels on Each Indicator

#### Analysis of Creative Thinking Skills Improvement

The results of the analysis of creative thinking skills of students who have done with some similarities statistics show an increase in creative thinking skills of students on each indicator. Here is a graphic presentation of an increase in critical thinking skills of students which is calculated by using the N-gain formula.

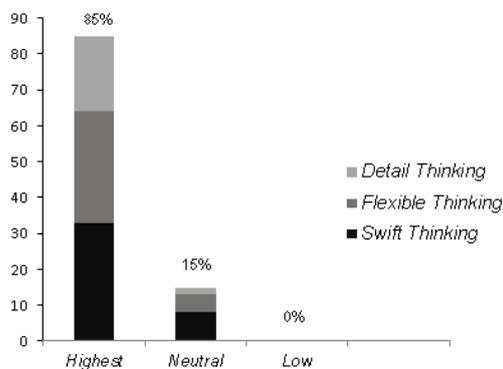
**Table 4.** N-Gain Criteria for Each Creative Thinking Skills Indicators

Indicator	N-Gain	Criteria
Thinking Swiftly	0,55	Moderate
Thinking Flexibly	0,95	High
Thinking in detail	0,72	High

Table 2 shows that there are two indicators of creative thinking which has increased in high criteria namely think flexible and think in detail, while the indicator of swift thinking increased in moderate criteria. Thus, the increase in creative thinking skills of students in general is high. This shows that after the learning process by using Macromedia Flash and multimedia coupled with the implementation of a simple lab works, students have been able to find the concept of motion well. Students no longer think on the surface pattern but have been able to generalize any findings into the example in the vicinity. This is because through the Macromedia Flash multimedia animation students have been invited to be directly in-

involved in the process of observation through Macromedia Flash multimedia, followed by testing using simple equipment.

Improvement in creative thinking skills of students overall has reached high and medium categories. More specifically the percentage of each category is evident from the results of pre-test and post-test as well as N-Gain value from each student that has been done. The number of students who achieve increased creative thinking skills categories of high, moderate and low are 0%, respectively. Here is a specific chart based on the percentage of high, medium, and low to the increasing of students' creative thinking skills (Figure 3).



**Figure 3.** Percentage of N-Gain Score of Each Indicator Of Students' Creative Thinking

#### Overview on the Hypothesis Data Distribution Normality Test

Normality test is principally conducted to determine whether the data are normal or randomly distributed. Testing data normality will involve some statistic methods. The following is a presentation table containing the results

processed data of pre-test and post-test to determine the normality of the data distribution. The results obtained are as Table 5.

Based on Table 5, it appears that the test result data pre-test and post-test from students of the first semester of Physics education department obtained on value  $\chi^2_{count} = 4.98$ , while  $\chi^2_{table} = 16.9$  for 95% level of confidence, with degree of freedom (df) = k-1. These data show that the calculated value < table which means the pre-test result data are distributed normally. List of table value for each df can be seen on the table H statistics. Similarly for post-test results data the same test were performed. Post-test scores obtained count value = 5.94, while the table values = 16.9 for 95% level of confidence and degree of freedom df = 3. This result also shows that the calculated value < table which means that data on post-test results also distributed normally.

#### Statistical Analysis t-test

To determine the significance of differences in pre-test and post-tests results, then the data should be statistically analysed with different test statistic, the t-test. The t-test can be performed after both data distribution were found to be normally distributed. The results of the t-test for experimental class, that is first semester students of Physical education department after have been taught using interactive multimedia (Macromedia Flash) is as follows:

The results of the statistical calculation that has been recapitulated in the table above shows that the obtained value t count is 23.21, while the obtained value of t table is 1.72 t that is considered by the degrees of freedom (df) = N-1 and the significant level  $\alpha = 0,05$ . These

**Table 5.** Normality Test Results of Pretest and Posttest Data

Class	n	df	$\chi^2_{count}$	$\chi^2_{table}$	Criteria		Information
					Accept $H_a$	Reject $H_a$	
Pretest	35	9	4.81	16.9	$\chi^2_{count} < \chi^2_{table}$	$\chi^2_{count} > \chi^2_{table}$	Normal
Posttest	35	9	5.94	16.9	$\chi^2_{count} < \chi^2_{table}$	$\chi^2_{count} > \chi^2_{table}$	Normal

$$\alpha = 0,05$$

**Table 6.** T-test of Pre-test and Post-test Score

Gain Amount ( $\sum d$ )	Xd <sup>2</sup>	Median	df	T <sub>count</sub>	t <sub>table</sub>	Criteria		Information
						Reject $H_o$	Accept $H_a$	
972	1689.86	42.26	22	23.21	1.72	$T_{count} < t_{table}$	$T_{count} > t_{table}$	Accept $H_a$ and Reject $H_o$

figures indicate that the value of  $t$  count  $>$   $t$  table which means that the hypothesis is accepted or  $H_0$  is rejected and  $H_a$  is accepted at significance level  $\alpha = 0.05$ . This significantly shows that the use of interactive multimedia (*Macromedia Flash*) can improve creative thinking skills of students in basic physics course. The use of interactive multimedia is also accompanied by experimental activity directly done by students after observing the display of multimedia which has been set by the lecturers. The result of these findings, shows that high-level thinking skills of students, one of which is the ability to think creatively can be developed through the media and direct practice test. Results obtained after learning by using interactive multimedia is very different from the data obtained prior to the treatment. These findings provide a conclusion to the author that learning by involving the entire area of intelligence and motor skills of the students can make students recognize each of the concepts of physics better.

### Discussion

In studying physics it is important to note the appropriate model or learning strategies when starting the learning process, because the right-on-target model or learning strategy and in accordance with the desired competencies will facilitate the students to master a particular concept. Models and strategies will also contribute to the success of achieving the learning objectives. The learning model is presented by an educator does not merely have to be glued in the form of innovative learning model that lately has been offered to fix a learning process. Learning model can also be a product of a media that is able to bring the learners to enjoy the learning process. As well as the use of interactive multimedia (*Macromedia Flash*) is also accompanied by the simple practical activity turned out to give a different colour on the increased ability of creative thinking of first semester students of physical education department. Live demo in the form of a simple lab work are performed using simple equipment such as cars kids, baseball, and others. The use of a simple apparatus, intended by the researchers so that student as a candidate teacher can understand, that in order to encourage students to learn physics, they do not always have to deal with expensive equipment and sophisticate as it is available in the laboratory of physics. Expensive and hard to get equipment is often used as an excuse

by many teachers to teach physics only on the surface patterns or concepts that are actually just an activity of memorizing and counting. Related to the findings on success through simple practical tools media and interactive multimedia has confirmed the findings which has been done previously in 2015, Marnita (2016) found that the application of problem-based learning assisted simple hydraulic pump can improve students' critical thinking, and further the activities of teachers in managing learning by using problem-based learning-assisted simple hydraulic pump classified as very good.

The use of interactive multimedia (*Macromedia Flash*) as has been done can be used as a reference for teacher candidates at the Al-muslim University when they are about to do their final research assignment. For a teacher any interactive multimedia (*Macromedia Flash*) which is accompanied with simple lab works can be used as a solution to the application of appropriate learning models while teaching. Interactive multimedia (*Macromedia Flash*) can invite a learner, in this case is the first semester students of Physics education department to directly engage fully in learning. The involvement began with the use of the senses to observe directly any movement or animation displayed, which animated the movements that generally they encounter in their environment. Furthermore, the involvement of students also occurs when the entire motor, the left brain and right brain has to be able to use and apply the simple equipment that exists into a variety of styles and effects form the style of Newton's laws. This causes students to think actively to resolve any responsibility given to them in the learning process.

Based on the research that has been conducted by researchers at the first semester students of Physic education department, it can be conclude that the use of interactive multimedia (*Macromedia Flash*) can improve creative thinking skills of students, namely ability to think fluently, flexible thinking and detailed thinking. These findings suggest that the ability for reflection of the students when confronted with learning activity by using interactive multimedia have triggered them to use their mind in order to develop their creative thinking abilities. In line with it, Hipkins (2006) stated that the development of generic skills in the students themselves needs to be facilitated so that they can reflect themselves. Based on the findings, the use of interactive multimedia (*Macromedia Flash*) can improve creative

thinking skills of students. It can be said that the findings are consistent with the study conducted by Sumarni, Sudarmin, & Kadarwati (2013) entitled "Improving multimedia-based learning for mastery of chemistry concepts and thinking skills students". The study found that the application of interactive multimedia based MPK (Model Pembelajaran Kimia = Chemistry Learning Model) able to improve the mastery of chemistry concepts, integrated high-level thinking skills of chemistry teacher candidates to the level of N-Gain high category for the ability of critical thinking, creativity, the ability to decide and problem solving".

The success of this research can also be seen from the two indicators of creative thinking that has increased in high criteria, namely think flexible and think in detail. While the indicator of thinking swiftly increase in moderate criteria. On the criteria of thinking swiftly, the student is required to pour new ideas or new ideas that are relevant to the concept of Newton's laws which are being discussed. These demands make the most of the students who only study physics at the surface pattern in previous secondary school, have difficulty in exploring their ideas. Thus, an increase in creative thinking skills of students in general is high. In addition the results of t-test statistical calculations also show that the value  $t_{count} > t_{table}$  which means that the hypothesis is accepted or  $H_0$  is rejected and  $H_a$  is accepted at significance level  $\alpha = 0.05$ . Increased students' creative thinking skills which on average is in the high category indicates that student enthusiasm for learning is very high. During the learning process the students are excited, passionate and highly motivated to understand and apply the concept of Newton's laws which are being discussed. The results of the research that has been found by this writer, reinforces the findings of a study conducted by Widodo et al (2010) who found that MMI has given students the opportunity to skilfully use the framework of logic, logical consistency, and the law of cause and effect.

## CONCLUSION

From the results of this study it is concluded that the use of interactive multimedia (*Macromedia Flash*) can improve creative thinking skills of students. It can be seen from the indicators of creative thinking, namely thinking flexibly and thinking with detail that increased in

high criteria, while the indicator thinking swiftly has increased in moderate criteria. In addition, the results of t-test statistical calculations also show that  $t_{count} > t_{table}$  which means that the hypothesis is accepted or  $H_0$  is rejected and  $H_a$  is accepted at significance level  $\alpha = 0.05$ .

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## THE DEVELOPMENT OF QUESTIONNAIRE TO INVESTIGATE STUDENTS' ATTITUDES AND APPROACHES IN PHYSICS PROBLEM SOLVING

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### ABSTRACT

This study aims to develop physics problem solving survey utilized to obtain students' attitude and approach while solving physics problem. Several steps are conducted to develop the survey: validating, computing reliability, and testing. This research involves Physics Education students-Tanjungpura University who study at Fourth and Sixth semester. Furthermore, after questionnaire administered to the students, data are analysed through determining average score of the students and computing average percentage of students who are agree, neutral, and disagree based on semester and gender. The results show that the sixth semester students' responses are more expertlike than those of the fourth semester students and female students are less expert than those male students. Based on semester and gender, majority of students have the same attitudes and approaches while solving problems. Students and experts have different attitudes about the role of mathematics in problem solving.

### ABSTRAK

Penelitian ini bertujuan untuk mengembangkan angket yang digunakan untuk mengetahui sikap dan pendekatan mahasiswa pada saat menyelesaikan soal fisika. Tahapan yang dilakukan dalam mengembangkan angket tersebut adalah melakukan validasi, menghitung reliabilitas, dan mengujicoba. Penelitian ini melibatkan mahasiswa Pendidikan Fisika semester IV dan VI – Universitas Tanjungpura. Setelah angket tersebut diberikan kepada mahasiswa, analisis data dilakukan yaitu menghitung skor rata-rata mahasiswa untuk setiap item dan secara keseluruhan, menghitung persentase rata-rata mahasiswa yang sesuai, netral, dan tidak sesuai dengan sikap dan pendekatan ahli berdasarkan semester dan jenis kelamin. Hasil penelitian menunjukkan bahwa mahasiswa semester VI lebih sesuai dengan sikap ahli atau lebih berpengalaman dibanding dengan mahasiswa semester IV dan sikap mahasiswa laki-laki lebih sesuai dengan sikap ahli dibandingkan dengan mahasiswa perempuan dalam menyelesaikan soal. Kemudian, ditinjau berdasarkan semester dan jenis kelamin, sebagian besar mahasiswa memiliki sikap dan pendekatan yang sama dengan ahli dalam menyelesaikan soal. Mahasiswa dan ahli memiliki sikap yang berbeda tentang peran matematika dalam mengerjakan soal.

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**Keywords:** Attitudes; Approach; Physics problem solving; Survey

### INTRODUCTION

Physics is one of science subjects taught from high school to college. During the study of physics, most students have difficulty under-

standing the concepts of physics and solving physics problems. Most students assume that physics courses are the same as mathematics because they generally use equations to solve physics problems (Bryan & Fennel, 2009). When solving the problem of physics, students often go directly to mathematical equations and result in not having enough steps to find the

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right answer. For example, when a question is presented in verbal form, students tend to use the formula immediately without thinking of a strategy to understand the problem (TMS & Sirait, 2016). As a result, most students are unsuccessful in determining the correct answer.

The ability to solve problems is very important in learning science especially in physics (Docktor, Strand, Mestre, & Brian, 2015; Mason & Singh, 2016). From a pedagogical point of view, problem solving can be used as a tool for evaluating student learning (Heller, Ketih, & Anderson, 1992). These issues are usually displayed at the end of each chapter of physics textbooks and other disciplines of science. In addition, teachers can also provide questions to evaluate students' understanding at the end of the lesson and at the end of a course or lecture.

To help students successfully solve physics problems, strategies for solving physics problems have been developed in physics education research. Heller et al., (1992) has developed a problem solving strategy that includes the following steps: 1) visualizing the problem, 2) explaining the problem based on the physics concept, 3) planning a solution, 4) executing the plan, and 5) checking and evaluating. Another physics problem solving strategy is a qualitative solution (Leonard, Dufresne, & Mestre., 1996). This strategy has three main components, namely 1) sets out the main principles or concepts that can be applied to solve problems, 2) justifies principles or concepts to apply, and 3) applies principles or concepts to achieve an answer. Therefore the operational definition of a qualitative settlement strategy is what, why, and how the answer to the question.

The next strategy is an explicit solving strategy. This strategy is part of the learning process by directly teaching students how to use higher techniques to solve problems (Huffman, 1997). Solving problems in textbooks often only presents steps in general and usually emphasizes quantitative aspects. Explicit problem solving tends to emphasize both qualitative and quantitative aspects. The explicit problem solving steps are as follows 1) focusing on the problem, 2) explaining the problem in the physical context, 3) planning the solution, 4) executing the plan, and 5) evaluating the answer. Furthermore, these steps are almost similar to those made by Heller et al. (1992).

The latter strategy is a concept-focused strategy. Docktor et al. (2015) developed a modified physics-problem-solving strategy from

Leonard et al. (1996) called the conceptual breakdown. This strategy includes three important parts of the principles (principles or concepts that are appropriate for the problem), justification (explanation of why principles or concepts are appropriate), and plans (a number of steps that present ways to solve problems and include mathematical equations).

In addition to strategy, assessment rubrics are also developed. Kuo, Hull, Gupa, & Elby (2012) and Hull et al (2013) create a rubric that combines conceptual and mathematical reasoning. This rubric can evaluate the work of students who do not follow formal strategies. In addition, Docktor et al. (2016) designed an assessment rubric containing several items including 1) useful descriptions, 2) physics approach, 3) more specific physics applications, 4) mathematical steps, and 5) logical answers.

Research on physics problem solving generally focuses on improving students' abilities through strategies or approaches, giving scaffolding (Lin & Singh, 2015), and also how students can solve problems effectively (Mason & Singh, 2010a; 2016). The study of students' attitudes or approaches to physics is limited. The attitude and approach of students to learning has a significant influence on the objects being studied by students. Mastering physics not only develops the knowledge structure of the physics concept but also develops productive attitudes about knowledge and physics learning (Balta, Mason, & Singh, 2016).

A team of researchers from the University of Maryland developed an instrument to explore students' attitudes and expectations toward learning physics. The questionnaire is the Maryland Physics Expectation (MPEX) (Redish, Saul, & Steinberg, 1998). Questionnaire consists of 34 items with answers agree or disagree and given before and after learning. Furthermore, Colorado Attitudes about Science Survey (CLASS) is a similar questionnaire with MPEX that explores students' attitudes about physics teaching (Adams et al, 2006). Based on the data analysis shows that qualitatively the results obtained are the same as the results obtained using MPEX. Then, Attitudes toward Problem Solving Survey (APSS) consists of 20 statements used to explore students' attitudes toward the completion of physics problems (Cummings, Lockwood, & Marx, 2004). Indicators developed from MPEX by focusing on how to solve physics problems in textbooks such as the role of formulas or mathematical equations, the importance of physics concepts,

strategies or approaches used in solving physics problems. The questionnaire given to students before and after lectures at three different universities. Furthermore, Attitudes and Approaches to Problem Solving (AAPS) were developed from APSS consisting of 33 statements with five answers that strongly agree, agree, neutral/do not know, disagree, and strongly disagree. The questionnaire was given to physics lecturer, physics graduate student, and physics undergraduate student (Mason & Singh, 2010b).

Inspired by the results of research at several universities abroad, this study aims to develop a Physical Problem Solving Questionnaire (PPSQ) that has been validated and ready to be used to explore the attitude and approach of physics teacher candidates when doing physics. This questionnaire was developed from several findings that students' view of physics learning influenced success in physics learning (Roth, 1994; May & Etkina, 2002; Lising & Elby, 2005). The indicators in this questionnaire consist of several aspects such as concepts, formulas or equations, representations, strategies, and interests in solving physics problems (Redish et al., 1998; Adams et al., 2006; Balta et al., 2016). Development of this questionnaire is very important to do because there is still limited questionnaire about how students solve the physics problem in the Indonesian format. In fact, lecturers can use this questionnaire in their learning as a way to assist students in solving physics problems.

## METHOD

The questionnaire developed in this study was adapted from Attitudes and Approaches to Physics Problem Solving (Mason and Singh, 2010b; Balta et al., 2016). Questionnaire is translated first from English to Indonesian. Furthermore, the questionnaire was then validated by five physics lecturers to determine the suitability of the questionnaire statement with the content of physics. In addition to the physics lecturer, the questionnaire was also validated by five physics semester final students who are working on the final project. Students are involved to know the legibility of each statement in the questionnaire. This validation step follows a strategy by Mulford and Robinson (2002) by involving students to evaluate the readability of the chemical concept test. The validation of the content, which measures the ease of understanding the statement (Barniol

& Zavala, 2014) consisting of four options that are very easy to understand (4), easy to understand (3), elusive (2), and very elusive (1). The next step was calculated the average score of each item statement and overall. The average criterion score of each statement fit of use is greater than or equal to three.

After the questionnaire was validated, the questionnaire was given to 10 students as a test to find out whether there was still a confusing statement and also to know the time needed to fill in the questionnaire. Gall, Gall, & Borg, (2005) stated that an initial test or evaluation of the instrument could involve six to 12 participants.

The questionnaire reliability was also measured using Alpha Cronbach (Fraenkel & Wallen, 1993; Cortina, 1993).

$$\alpha = \left( \frac{K}{K-1} \left( 1 - \frac{\sum S_j^2}{S^2} \right) \right)$$

where

K = the number of questions

$S_j^2$  = the value of variance of answer to question j

$S^2$  = the value of variance of total scores

The expected reliability value ( $\alpha$ ) of the questionnaire and appropriately used is greater than or equal to 0.7.

Physical Problem Solving Questionnaires (PPSQ) consist of 30 statements with five choices of answers: strongly agree, agree, neutral or ignorant, disagree, and strongly disagree. The indicator of the questionnaire is the use of representation, mathematical roles and formulas, re-examine answers, the role of concepts, discuss and ask questions, problem solving strategies, and interest in solving problems.

To find out the attitude and approach of students to solving the physics problem, the questionnaire was given to Physics Education students of Tanjungpura University in the fourth and sixth semesters, amounting to 150 people with 45 men and 105 women. This student will be a physics teacher at Junior High School and High School after completing their studies. Questionnaires are given at the time the students take the course. The student's answer is given a score of 1 if it corresponds to an expert answer, a score of 0 for a neutral pick, and a score of -1 for answers that do not match the expert's answer (Mason & Singh, 2010b). Answer very agree and agree given the same score and also vice versa to disagree and strongly

disagree. Then the student scores (semesters IV, VI, Male, and Female) are calculated for each item. Next, calculate the average percentage of students corresponding to the expert's answer, neutral/ignorant, not according to the expert, and not answer (Marx & Cummings, 2007).

## RESULTS AND DISCUSSION

The indicators and examples of the PPSQ statements are shown in Table 1. Before the questionnaire was given to the students, the questionnaire was validated first by a physics lecturer as well as a student. The validation is validation of the content to measure the

compatibility between the statement with the physics learning and also the degree of ease of understanding the statement. Validators are required to score from score 1 to 4 (very elusive, elusive, easy to understand, and very easy to understand).

Based on the calculation, the average validity questionnaire score conducted by the lecturer (five persons) is 3.43 (easily understood category). For more details, the average validity score for each questionnaire is shown in Table 2. However item 2 has a score of 2.8 so it needs to be discussed with the validator before being further validated by the student. The word "visualize" is changed to "sketch".

Furthermore, the questionnaire was also

**Table 1.** Indicators and Examples of Statement of Questionnaire

Indicators	Number of Statements and item number	An example statement in a questionnaire
Use of representation	5 [2,14,16,17,18]	Saya sering membuat sketsa (gambar, grafik, diagram, dll) berdasarkan situasi atau permasalahan yang diberikan dalam soal (I often sketch (pictures, graphics, diagrams, etc.) based on the situation or problem given in the question)
The role of mathematics and formulas	4 [3,5,10,11]	Pada dasarnya, mengerjakan soal fisika adalah memasukkan angka-angka ke dalam rumus (Basically, working on the physics problem is to insert the numbers into formulas)
Recheck the answer	4 [19,21,24,28]	Jika jawaban saya tidak masuk akal, saya memeriksa kembali jawaban itu untuk melihat letak kesalahannya (If my answer does not make sense, I double-check the answer to see where the error lies)
The role of physics concepts	4 [4,13,15,20]	Langkah pertama dalam mengerjakan soal fisika, saya mengidentifikasi prinsip-prinsip fisika (The first step in working on the physics problem, I identify the principles of physics)
Discuss or ask question	3 [1,6,23]	Apabila mengalami kesulitan menyelesaikan soal pekerjaan rumah (PR) fisika, saya berpikir untuk berdiskusi dengan teman (If I have trouble completing my physics homework, I think to discuss with friends)
Completion strategies	6 [7,8,9,12,25,27]	Jika saya menggunakan dua cara/strategi yang berbeda untuk menyelesaikan suatu soal dan jawabannya berbeda, saya akan berpikir lagi untuk memilih cara yang lebih masuk akal (If I use two different ways / strategies to solve a problem and the answer is different, I will think again to choose a more sensible way)
Interest in solving problems	4 [22,26,29,30]	Saya senang menyelesaikan soal fisika meskipun soal itu relatif sukar dan menyita waktu (I like to solve the physics problem even though the problem is relatively difficult and time consuming)

**Table 2.** Validation Results

Indicators	Validator	Average validation score of each item					
Use of representation		2	14	16	17	18	
	Lecturers	2.8	3.8	3.6	3.4	3.6	
	Students	3.6	4.0	4.0	3.6	4.0	
The role of mathematics and formulas		3	5	10	11		
	Lecturers	3.6	3.2	3.4	3.6		
	Students	4.0	3.6	3.2	3.4		
Recheck the answer		19	21	24	28		
	Lecturers	3.8	3.2	3.2	3.4		
	Students	3.8	3.6	3.6	3.8		
The role of physics concepts		4	13	15	20		
	Lecturers	3.0	3.4	3.2	3.2		
	Students	3.4	4.0	3.8	3.8		
Discuss or ask question		1	6	23			
	Lecturers	3.4	3.2	3.6			
	Students	3.4	4.0	3.8			
Completion strategies		7	8	9	12	25	27
	Lecturers	3.4	3.8	3.2	3.0	3.0	3.8
	Students	4.0	3.4	2.8	3.4	3.4	3.8
Interest in solving problems		22	26	29	30		
	Lecturers	3.6	4.0	3.6	3.8		
	Students	3.4	3.8	4.0	3.6		

validated by students with five validators. The average score of 3.65 is easily understood but there are still two statements (9 and 20) scoring below 3. Therefore interviews with validators are used to improve a more understandable word or phrase. Statement number 9 slightly confuses the validator against the word “way and strategy”. As for item 20 distinguish between “context” and “situation”. Based on the interview results obtained that the word “strategy” and “situation” better known by students. After the score of each statement is greater than or equal to 3 (easy to understand category), the next step is to test the students to find out the time required to fill the questionnaire and also whether there is still a sentence or word that is still confusing. Based on the results of the experiments obtained that the average student answered the questionnaire 10 to 25 minutes, so it was decided the time to fill the questionnaire is 20 minutes.

Then, the questionnaire reliability is also calculated using Alpha Cronbach. Results obtained for 0.73 which means 0.1 points lower than the questionnaire of physics solving by Mason and Singh (2010) and Balta et al (2016). Nevertheless this questionnaire is still accep-

table and worthy of use (Cortina, 1993; Wilcox & Lewandowski, 2016)

Students in general, on average have taken over 60 semester credit units and also they have taken the core courses of physics courses such as Basic Physics, Mechanics, Thermodynamics, Waves and Optics, and others. Thus, it is assumed that students have often solved the problems of physics both in the form of assignment and during the midterm exam or the final exam of the semester.

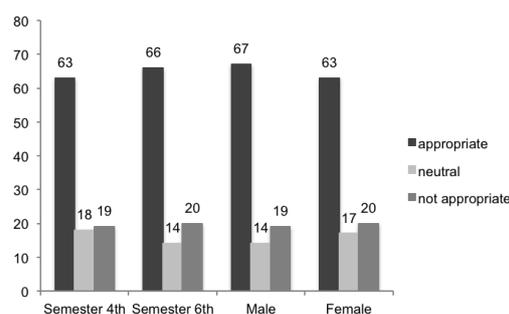
PPSQ consists of 30 statements with five answer options. The nine items have disagreeable or strongly disagreeable answers that correspond to the expert answers experienced in solving the physics problem and 21 items have the answer agree or strongly agree. Students are required to fill the questionnaire according to the time specified. Questionnaires were collected and then analyzed based on semester taken as well as gender.

Student responses corresponding to expert answers are given a score of 1, which is neutral or or unknown given a score of 0, and which is not in accordance with the expert's answer given a score of -1. The next step is to calculate the average score of each item based

on semester and gender. According to the data analysis, it is found that the average score of the students in the fourth semester is 0.44 while the average score of the sixth semester students is 0.46, slightly higher than the fourth semester. This means that the attitude and approach of completing the problems of sixth semester students more appropriate with experts or experienced. For both men and women, the mean scores were 0.48 and 0.44, respectively. The average student score for each item is shown in Table 3. There are five items (1, 3, 10, 11, and 29) that have negative scores (shown in Table 3), meaning that for all of these items students generally conflict with attitudes and approaches by experts or people who have experience in solving physics problems.

The lowest score obtained by students is in the statement number 3 and number 11. In point 3, 95% of students assume that mathematics is the most important thing in solving the problem. Data obtained by Mason and Singh (2010) show that approximately 50% of physics graduate students agree with this statement. Then, 50% of undergraduate students in Turkey also agree with item no 3 (Balta et al, 2016). This proves that when students enter physics class or study physics, mathematics becomes the main capital. Though understanding concepts, principles, physics law is important in learning physics (Docktor et al, 2015). Furthermore, to point 11, 95% of students assume that equations or physical formulas can only be used to solve certain problems. Furthermore, for item 29, about 70% of students

more easily complete the number calculation compared to symbols or formulas. This shows that students tend to solve problems relying on formulas or mathematical equations. Then, for these five points, students can be categorized at the beginner level or lack of experience, supported also by point 1 that students tend to end their effort when they do not know the right steps to solve the problem.



**Figure 1.** Histogram of Average Percentage of Student Attitude

The number of students for each group that has an appropriate, neutral, and inconsistent attitude with experts is also calculated and converted into percentages. The average percentage of students is shown in Figure 1. The histogram shows that the average score is over 50% of the students voted in favor of the expert attitude in solving the physics problem. The percentage of sixth semester students whose answers correspond to the experts is higher than the fourth semester students. That's because the sixth semester student has

**Table 3.** Average Scores

Item	1	2	3	4	5	6	7	8	9	10
Semester IV	-0.6	0.58	-0.9	0.87	0.14	0.53	0.45	0.8	0.83	-0.4
Semester VI	-0.5	0.68	-1	0.88	0.51	0.53	0.37	0.82	0.95	-0.2
Male	-0.5	0.64	-1	0.91	0.42	0.44	0.44	0.8	0.87	-0.4
Female	-0.5	0.60	-0.9	0.85	0.22	0.56	0.41	0.80	0.87	-0.3
Item	11	12	13	14	15	16	17	18	19	20
Semeste IV	-0.9	0.9	0.88	0.67	0.12	0.47	0.37	0.88	0.61	0.67
Semeste VI	-1	0.86	0.91	0.86	0.04	0.70	0.67	0.96	0.47	0.68
Male	-0.9	0.93	0.96	0.73	0.2	0.64	0.62	0.84	0.58	0.8
Female	-0.9	0.86	0.86	0.74	0.04	0.52	0.42	0.93	0.55	0.61
Item	21	22	23	24	25	26	27	28	29	30
Semeste IV	0.89	0.41	0.89	0.87	0.63	0.65	0.91	0.9	-0.5	0.62
Semeste VI	0.88	0.40	0.84	0.82	0.70	0.42	0.93	0.84	-0.3	0.18
Male	0.82	0.56	0.76	0.91	0.71	0.69	0.93	0.91	-0.2	0.22
Female	0.91	0.34	0.92	0.82	0.63	0.50	0.91	0.86	-0.5	0.55

more experience in solving the physics problem. Furthermore, men have more experience than women, as evidenced by the percentage average of 67% and 63% respectively.

The average score of each indicator is shown in Table 4. The indicators of the use of representations (pictures, diagrams, graphs, etc.) are items 2, 14, 16, 17, and 18, scored an average of 80% for students in the sixth semester while semester students fourth around 65% utilize multi representation when solving the problem. By gender, the average percentage of men using multi representation is higher than that of women, which is 78% and 73% respectively. Kohl and Finkelstein (2005) and Rosengrant, Etkina, & van Heuvelen (2006) suggest that students who often use good representation when completing homework as well as exams have higher problem solving abilities.

Furthermore, Savinainen, Makynen, Nieminen, (2013) states that interaction diagram representation can help students to identify kind of force and draw the force diagrams. The TMS and Sirait (2016) study showed that students trained using motion diagrams have better conceptual mastery skills. Students with good vector representation skills tend to successfully identify the force diagram correctly (Sirait, Hamdani. & Octavianty, 2017). In addition, the use of representations greatly assisted students in studying electricity and magnetism (Kustus, 2016) and illustrating the diagram greatly helped students learn electric force and electric fields (Cao & Brizuela, 2016).

Indicators of the role of mathematical equations and formulas in the completion of physics problems are listed in 3, 5, 10, and 11. Around 33% of students of the fourth semester agree that working on the problem of physics is simply entering numbers into formulas. Meanwhile, the sixth semester students are more understanding in the use of equations or formulas, only 16% of students agree to the statement. Mathematics is needed as a language to solve the problem of physics, but not just use the formula rather than understand the meaning of the equation in the physical context (Redish & Kuo, 2015). Then, the percentage of men corresponding to the attitude of experts or experienced in terms of use of formulas or equations is higher than that of women ie. 62% and 50% respectively.

In addition, the practice of solving the problem with various strategies is also important for successful completion of the problem. For example, in points 12 and 27 on strategies for solving problems, the majority of students (more than 90%) have an attitude consistent with scientists or experts. This indicates that students need to be equipped with various problem solving strategies such as qualitative problem solving (Leonard et al, 1996), conceptual (Dockett et al, 2015), and explicit (Huffman, 1997). In addition to strategy, other factors that may help the student in solving problems or problems are beliefs of his or her own ability (Yuliarti et al, 2016) and reflective thinking skills (Ellinawati, Rusdiana, Sabandar,

**Table 4.** Average score of each indicator

Indicators	Item number and Average score of each item					
Use of representation	2	14	16	17	18	
	0.63	0.77	0.59	0.52	0.92	
The role of mathematics and formulas	3	5	10	11		
	0.95	0.33	-0.3	-0.95		
Recheck the answer	19	21	24	28		
	0.54	0.89	0.85	0.87		
The role of physics concepts	4	13	15	20		
	0.88	0.9	0.08	0.68		
Discuss or ask question	1	6	23			
	-0.55	0.53	0.87			
Completion strategies	7	8	9	12	25	27
	0.41	0.81	0.89	0.88	0.67	0.92
Interest in solving problems	22	26	29	30		
	0.41	0.54	-0.4	0.4		

& Rusli, 2014).

Students' attitudes to ask or discuss with peers when having difficulty when working on physics are shown in the numbers 1, 6 and 23. The average percentage of fourth semester students who ask colleagues is higher than the students of sixth semester that is 80% and 74%. Heller and Hollabaugh (1992) stated that students who taught the completion of physics problems in groups have higher problem-solving abilities than the individual classes. In addition, Mason and Singh (2010a) research results also show that feedback with peers can help students to solve physics problems.

The student's response about re-examining the results of work on physics both assignments and exams have a high percentage. For each item shown at numbers 19, 21, 24, and 28, over 70% of students responded positively. That is, students take the time to check the answers and also investigate where the mistakes they are doing. Zimmerman (1998) said that one of the characteristics of students who succeed in learning is to re-examine the task before submitting to the lecturer.

### CONCLUSION

Based on the results of the research can be concluded that the sixth semester students more experienced than the fourth semester in solving the physics problem. This means that attitudes will change with age and experience. Then in terms of gender, men respond more positively or in accordance with experts than women.

Questionnaire completion of physics is expected to be one tool to obtain information about attitudes and approaches of students at the time of completing the matter of physics so that teachers can strive in helping students improve the ability of completion of physics problems. Given the attitudes and approaches of students to problem solving can affect success in answering questions. Furthermore, further research needs to be done to find correlation between attitude and approach of student with ability of physics problem solving.

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# THICKNESS DEPENDENCE OF MAGNETIC SWITCHING DYNAMICS OF BARIUM-FERRITE AS A HIGH-DENSITY PERPENDICULAR MAGNETIC STORAGE MEDIA

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## ABSTRACT

Micromagnetic study of material thickness dependence of Barium-ferrite nano-dot magnetization dynamics has been performed. The used materials characteristics in this research represent the properties of Barium-ferrite. Barium-ferrite was modeled as a nano-dot with a surface area of  $50 \times 50 \text{ nm}^2$  and its thickness varies from 5 nm to 100 nm. This nano-dot was simulated using micromagnetic simulator software by solving Landau-Lifshitz-Gilbert equation. According to this study, obtained that the Barium-ferrite nano-dot has excellent thermal stability. Magnetization rate of this nano-dot decreases exponentially with the increase of thickness. The fastest magnetization rate observed in 5 nm of nano-dot thickness, meanwhile 45 nm for the slowest rate. Magnetization reversal mode of this Barium-ferrite nano-dot is dominated by domain wall nucleation and propagation. During the propagation of the domain wall, the exchange interaction becomes the main aspect compared to the other contributed energies.

## ABSTRAK

Telah dilakukan studi mikromagnetik pengaruh ketebalan material terhadap dinamika magnetisasi nano-dot *Barium-ferrit*. Karakteristik bahan yang dipergunakan di dalam penelitian ini mewakili karakteristik dari *Barium-ferrite*. Penelitian ini menggunakan sampel model berbentuk nano-dot berdimensi  $50 \times 50 \text{ nm}^2$  dengan variasi ketebalan 5 nm – 100 nm yang disimulasikan dengan menggunakan software simulator mikromagnetik dengan menyelesaikan persamaan Landau-Lifshitz-Gilbert. Dari simulasi ini diperoleh bahwa *Barium-ferrit* memiliki kestabilan termal yang baik, hal ini dibuktikan dari besarnya nilai energi tanggul. Diperoleh juga bahwa laju magnetisasi bahan cenderung menurun secara eksponensial seiring dengan meningkatnya ketebalan bahan. Laju magnetisasi yang terbesar terjadi pada ketebalan 5 nm dan yang terendah pada ketebalan 45 nm. Pola pembalikan magnetisasi nano-dot *Barium-ferrit* didominasi oleh pembentukan dan perambatan dinding-domain. Pada proses perambatan dinding-domain nano-dot *Barium-ferrit*, interaksi tukar memiliki pengaruh yang lebih besar dibandingkan penyusun energi yang lain.

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**Keywords:** Domain wall; Magnetic field; Magnetization; Switching field

## INTRODUCTION

Availability of high densities Hard-disk drive is emerging to answer the demand (Kim et al., 2015). In attaining the required densities, the storage unit should be downsized in nanometer (Kim et al., 2007) (Sadnawanto & Purnama, 2014). This reduction scale causes thermal instability (Wood, 2009)(Budi Purnama,

Koga, Nozaki, & Matsuyama, 2009) (Liu et al., 2016) and its information would be lost because of low magnetic energy (Ma & Liu, 2008). In overcoming this issues, the uses of perpendicular magnetic anisotropy (PMA) material as a storage unit media is required (Waseda et al., 2008) (Alebrand et al., 2012) (Azizah, Trihandaru, & Wibowo, 2016). The PMA material has tiny domain-wall which ensures more efficient motion during magnetic field induction (Jung, Kim, Lee, Lee, & Lee, 2008) (Woo et al., 2016).

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Limitation of scale ratio aspect in meeting the required stability can be solved by utilization of PMA material (Purnama et al., 2009). On the other hand, the magnitude of the driven field required to reverse the magnetization of the PMA material is too large so that the extended research on the magnetization dynamics at room temperature should be conducted (Hui, Cheng, Yan, Chen, & Miao, 2015). The magnetization dynamic is related to the external field either energy which consumed in the magnetization reversal.

The one aspect of this dynamic that important to be investigated is domain wall propagation (Cho, Jung, Cho, & You, 2015). In the last decades, various researchers have focused on the domain wall movement in the PMA thin-film (Metaxas et al., 2007; Mihai et al., 2013) which was motivated to understand the fundamental physics role of spintronic based devices (Shepley, Rushforth, Wang, Burnell, & Moore, 2015).

The geometry of ferromagnetic materials significantly affects the performance of various magnetic-based devices (Purnama, Prihanto, & Artono, 2013). One important aspect of this geometry is the thickness (Hui et al., 2015). In this paper, media thickness as one factor that controls the magnetization dynamics will be investigated numerically through micromagnetic study. As known from the previous research, media thickness plays an important role in the magnetization reversal which correlated to the read-write data (Hou & Krishnan, 2012) (Zhang, Li, Wang, Nie, & Guo, 2015). The magnetic material which investigated is Barium-ferrite. The uses of this material have various benefits. Beside of its large magnetic anisotropy, it also has the chemical stability that assures the durability (Lisfi & Lodder, 2002). The strong magnetic anisotropy is a fundamental feature required as a magnetic storage media with sufficient thermal stability (Shimizu et al., 2012). The purpose of this study is to examine the effect of Barium-ferrite thickness on the magnetization reversal characteristic of switching field, magnetization rate, and the dynamics of domain wall propagation.

## METHOD

To solve the magnetization dynamics of Barium-ferrite nano-dot, Equation (1) is used. (Budi Purnama et al., 2009)

$$\frac{d\mathbf{M}^i}{dt} = -|\gamma| \mathbf{M}^i \times \mathbf{H}_{\text{eff}}^i + \frac{\alpha}{M_{\text{sat}}} \mathbf{M}^i \times \frac{d\mathbf{M}^i}{dt} \quad (1)$$

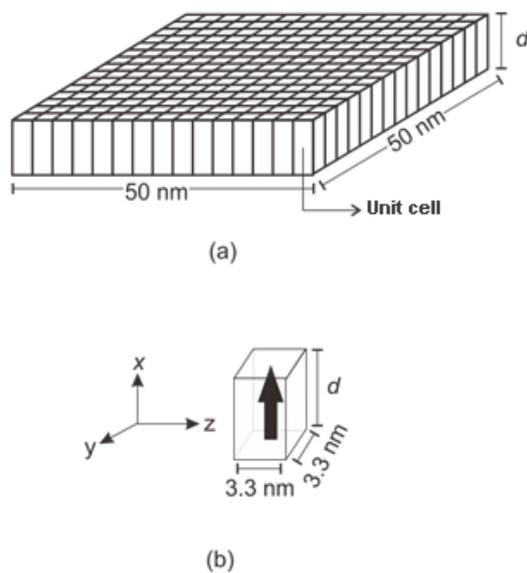
This equation called as Landau-Lifshitz-Gilbert (LLG) equation which the first and second terms respectively are described the gyromagnetic motion of magnetization and the damping factor. This damping cause the magnetization tends to parallel to the effective induced magnetic field. By using LLG equation, magnetization dynamics during exposed to the external magnetic field can be explained. In this equation,  $\mathbf{M}$  is the magnetization of the unit-cell,  $dt$  is the step integration as large as 0.25 ps,  $\gamma$  is the gyromagnetic ratio as large as  $1.76 \times 10^7 \text{ Oe}^{-1}\text{s}^{-1}$  (Lisfi, 2002),  $\alpha$  is the Gilbert damping factor, and  $M_{\text{sat}}$  is the saturation of magnetization of nano-dot.  $\mathbf{H}_{\text{eff}}$  is the effective induced magnetic field which acts as the resultant of a various factor that sourced from the external magnetic field and internal properties of materials which consist of anisotropy field ( $\mathbf{H}_k$ ), demagnetization field ( $\mathbf{H}_d$ ), and exchange field ( $\mathbf{H}_{\text{ex}}$ ) as given in Eq.(2) (Schrefl, Fidler, Suess, Scholz, & Tsiantos, 2006) (Herianto, Rondonuwu, & Wibowo, 2015):

$$\mathbf{H}_{\text{eff}} = \mathbf{H}_k + \mathbf{H}_d + \mathbf{H}_{\text{ex}} + \mathbf{H}_{\text{ext}} \quad (2)$$

The effective induced magnetic field which acts as a controller for the magnetic moment is attained from the differential of energy density,  $\epsilon$ , of unit cells with respect to magnetic moment as shown in Eq.(3).

$$\mathbf{H}_{\text{eff}} = -\frac{1}{M_s} \frac{d\epsilon}{d\mathbf{m}} \quad (3)$$

In this micromagnetic study, Barium-ferrite was modeled as a parallel-piped which called as nano-dot with the lateral dimension is  $50 \times 50 \text{ nm}^2$  with its thickness varies in the range of 5 nm up to 100 nm. The nano-dot is composed of  $15 \times 15$  of unit cells which shown in Fig.1. The unit cell only contains single magnetic moment. Interaction of adjacent unit cells was accommodated in the exchange interaction field. Meanwhile, the nano-dot is assumed as an isolated system.



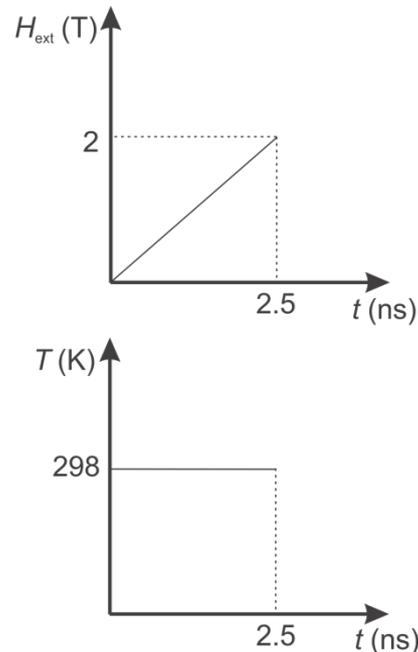
**Figure 1.** (a) Nano-dot Barium-ferrite, (b) unit cell (Herianto, Rondonuwu, & Wibowo, 2015)

The chosen intrinsic magnetic properties were magnetic saturation and damping constant as large as 4800 Gauss and 0.9 respectively (Boardman, 2005).  $6.3 \times 10^{-7}$  erg/cm and  $3.0 \times 10^6$  erg/cm<sup>3</sup> of exchange interaction and anisotropy constant respectively (Mansuripur & Connell, 1984).

In this study, Reduced Barrier Writing (RBW) simulation scheme was used. This scheme worked at room temperature which there was no contribution of thermal field. The magnetic field was exposed to the nano-dot with its magnitude increased linearly from 0 to 2 Tesla for 2.5 ns as shown in Fig.2. Through this scheme, principal information for magnetization reversal dynamics of Barium-ferrite at room temperature can be observed. Either thermal stability of Barium-ferrite or minimum energy that required to reverse the nano-dot magnetization can be determined. Furthermore, the magnitude of this barrier energy represents thermal stability level of the materials. Low barrier energy leads to the unsustainable recorded data in the magnetic storage media.  $60 k_B T$  is the minimum barrier energy level should be accomplished in order to store the information more than 10 years (Augustine et al., 2011).

The first step of this micromagnetic study is to evaluate the magnitude of the barrier energy. After the prerequisite of thermal stability is attained, the second step is to calculate the minimum magnetic field induction required to exactly switch the magnetic polarization which called as switching field,  $H_{swt}$ . The magnitude of

$H_{swt}$  was obtained by finding the magnitude of the field at which the normalized magnetization equal to zero. The third step is to calculate the magnetization rate. This rate is obtained from the gradient of the normalized magnetization curve.



**Figure 2.** Reduce Barrier Writing scheme (Herianto, Rondonuwu, & Wibowo, 2015)

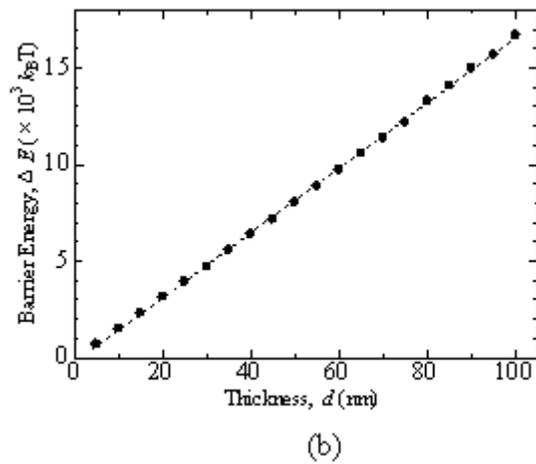
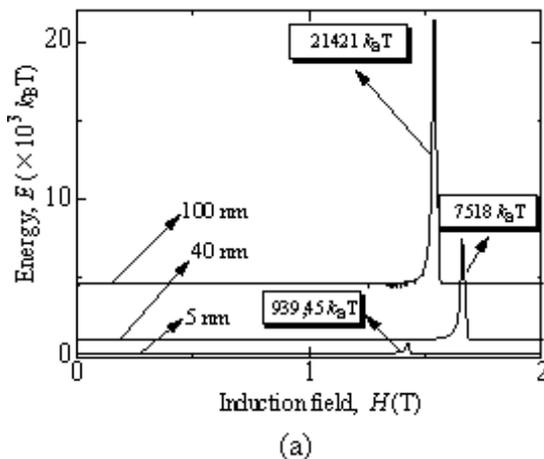
## RESULTS AND DISCUSSION

During exposed to the external magnetic field, the nano-dot has energy which composed from various source. This energy was defined as a scalar summation of the Zeeman energy ( $E_z$ ), exchange energy ( $E_{ex}$ ), the magnetic crystalline-anisotropy energy ( $E_K$ ), and demagnetization energy ( $E_D$ ) as shown in Eq.(4).

$$E = E_z + E_{ex} + E_K + E_D \quad (4)$$

The Zeeman energy is the energy of the nano-dot which appears as an interaction of magnetic moment with the external magnetic field. The exchange energy acts as a short-range interaction between the two neighboring spins. The magnetic crystalline-anisotropy energy of nano-dot is caused by the interaction of spins with the electron orbits which are related to the nano-dot crystallographic structure. Meanwhile, the demagnetization energy is the type of energy which connected to the interaction between magnetic dipole caused the formation of the magnetic domain. (Krone, 2011)

Energy profile of nano-dot for various thicknesses while exposing by external magnetic field is given by Fig.3(a). These energies are consisting of the two important values, i.e. maximum and minimum. The peak of this barrier energy is achieved at which the magnetization of nano-dot is exactly switched. Meanwhile, minimum energies are the state at which the nano-dot stay in equilibrium. The difference of both values is named as barrier energy,  $\Delta E$ . This barrier separates the two existing equilibrium state of nano-dot. The first equilibrium state is the condition of nano-dot at initial magnetization (before induced by external field). Meanwhile, the second equilibrium state is the condition at which the nano-dot has been magnetized in the induced field direction. Knowledge of about barrier energy is important. It gives the information of the required energy to reverse the magnetization of particular nano-dot. Thickness dependence of energy barrier is shown in Fig.3(b). This barrier highly depends on the thickness of the nano-dot. The energy barrier of the Barium-ferrite nano-dot for various thicknesses are larger than  $60 k_B T$  which means this material is compatible to be used as perpendicular magnetic storage media with excellent thermal stability. This barrier is rising linearly with respect to the increasing of the media thicknesses. The lowest value is obtained for 5 nm of the thickness with an appropriate barrier as large as  $717 k_B T$ . Meanwhile, the largest barrier is observed for 100 nm of the thickness with  $16.700 k_B T$  of the barrier value.

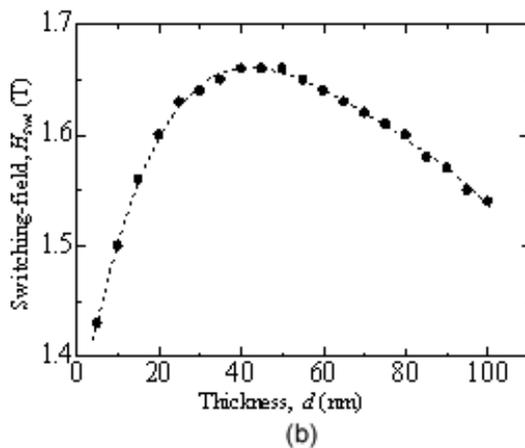
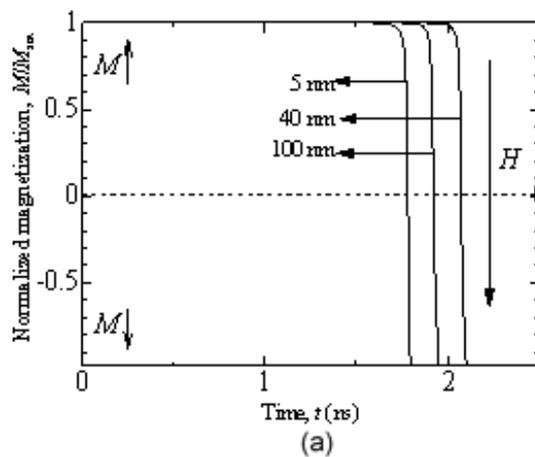


**Figure 3.** (a). The energy of Barium-ferrite nano-dot for three different thicknesses 5 nm, 40 nm, and 100 nm, (b). The barrier energy of Barium-ferrite nano-dot for various thicknesses at room temperature.

The magnetization of the Barium-ferrite nano-dot while exposed with 2 Tesla of external magnetic field is shown in Fig.4(a). Before induced by external magnetic field, initial magnetization of nano-dot lie in (x-) axis direction. Then, the nano-dot is induced by an external field which is directed in (x+) direction with its magnitude increase linearly from 0 up to 2 Tesla in 2.5 ns. Magnetization dynamics of nano-dot while exposed can be analyzed from the value of normalized magnetization,  $M/M_{sat}$ .  $M$  is the real-time magnetization of nano-dot, while  $M_{sat}$  is the saturation of the nano-dot magnetization. This norm-magnetization is equal to 1 at initial magnetization state which indicating both, either magnitude and direction of real-time magnetization are similar to the saturation magnetization of nano-dot. Along with the increasing of induction of magnetic field, this value is decreased. At the zero value of  $M/M_{sat}$ , entire magnetic moments of the nano-dot are perpendicular to its magnetic saturation (no one of the magnetic moments direction is parallels). At this point, the magnetization of nano-dot is exactly to switch. The associated time and induced field at this state are called as switching-time,  $t_{swt}$  and switching field,  $H_{swt}$  respectively. While increasing the induced field, the normalized magnetization will reach -1. At this value, nano-dot has been perfectly magnetized in line to the induced field; the magnitude of the magnetization is equal to its saturation however the direction is opposite. As observed in Fig.4(a), the switching time is also sensitive to the nano-dot thickness. From the chosen

thickness samples, nano-dot with 5 nm of the thickness has the fastest switching time as fast as 1,7825 ns, while the slowest one possessed by nano-dot with 40 nm of thickness as long as 2,0725 ns.

The impression of the nano-dot thickness to the magnitude of switching field is presented in Fig.4(b). For thickness interval 5 nm up to 40 nm, the magnitude of  $H_{\text{swt}}$  is magnified from 1.43 T to 1.66 T along with the increasing of nano-dot thickness. Meanwhile, this field is degraded from 1.66 T to 1.54 T along with the enlarging of the thickness in the range of 40 nm up to 100 nm.

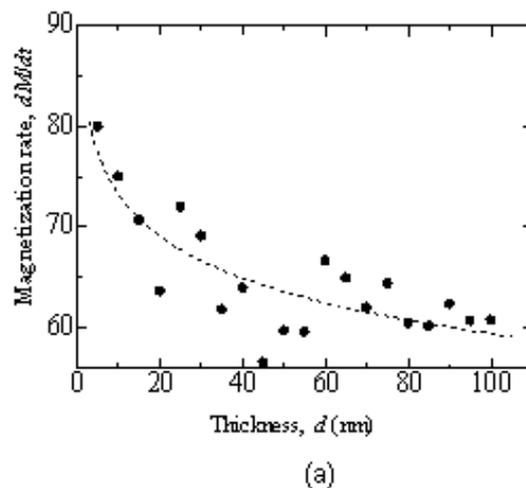


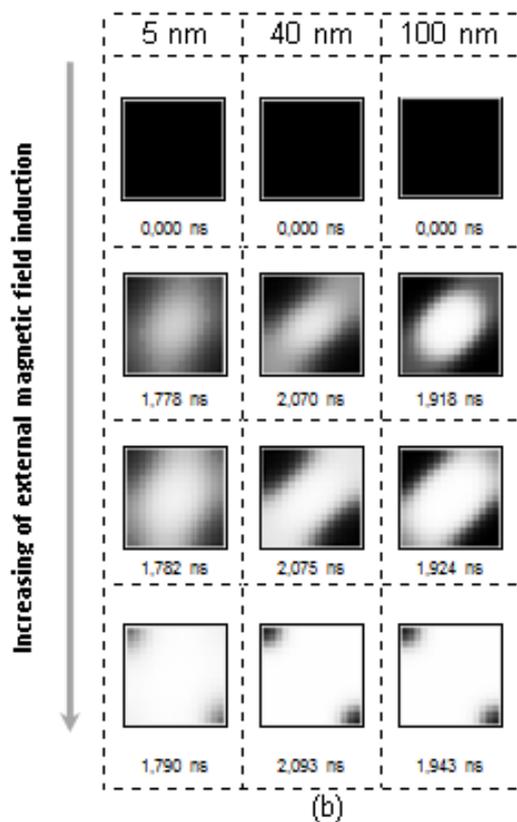
**Figure 4.** (a) The magnetization reversal of Barium-ferrite nano-dot for three different thicknesses 5 nm, 40 nm, and 100 nm, (b). The switching field of Barium-ferrite nano-dot for various thicknesses at room temperature.

The impact of the nano-dot thickness to the rate of nano-dot magnetization is shown in Fig.5(a). This rate tends to decrease exponentially along with the thickening of the nano-dot. Magnetization rate is highly sensitive to the

thickness in the range of 5 nm up to 50 nm. It means that more required time for thick nano-dot to be magnetized since its domain wall starts to nucleate. Meanwhile, magnetization rate tends to be constant over 45 nm of the thickness. This magnetization rate information is important for magnetic storage application which correlated to the efficiency of data recording. With fast magnetization rate, the utilization of this magnetic recording more efficient in time either energy consumption.

Visualization of magnetization mode for 5 nm, 40 nm, and 100 nm of thicknesses is shown in Fig.5(b). Initial magnetization state which has uniform magnetic moments direction of nano-dot is represented as a black area. At this state, magnetic moments of a nano-dot lie in ( $x+$ ) direction. Meanwhile, white area represents the magnetization in the opposite direction (in line with the external magnetic field). There is a transition area between the black and white regions which colored as gray. This region is called as domain wall. This domain wall separates two opposite domains that exist in a nano-dot. During the increasing of magnetic field induction, the domain wall is nucleated at the center of nano-dot. This means, the effective field at the center is highest than other area and the exchange interaction between neighboring unit cells dominate the interaction (Azizah et al., 2016). After this nucleation, domain wall propagates extensively so that the white area dominates the nano-dot. It is the final state at which a single domain realized.





**Figure 5.** (a). The thickness dependence of the magnetization rate of the Barium-ferrite nano-dot for various thicknesses at room temperature, (b). The visualization of magnetization reversal of Barium-ferrite nano-dot for three different thicknesses 5 nm, 40 nm, and 100 nm during induced by external magnetic field.

## CONCLUSION

Thickness dependence of the magnetization dynamics for Barium-ferrite nano-dot has been investigated using Landau-Lifshitz-Gilbert equation. As a result, the Barium-ferrite nano-dot has the excellent thermal stability which represented by its high barrier energy ( $> 60 k_B T$ ) for entire the chosen thicknesses. Temporarily, the magnitude of the switching field reaches its maximum value at 40 nm of thickness then decrease along as the thickening of nano-dot. This switching field reduction is followed by the increasing of thermal stability level. Moreover, the fastest and slowest magnetization rates are observed for 5 nm and 45 nm of the thicknesses respectively. The magnetization reversal mode is dominated by domain wall nucleation and propagation which exchange interaction takes more noteworthy control than another contributed energies.

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# IMPROVING OF THE STUDENT LEARNING IN LECTURES OF GENERAL PHYSICS I BY COLLABORATIVE LEARNING MODEL BASED ON SAINTIFIC APPROACH

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## ABSTRACT

This research aim is improving the learning outcomes of the students on General Physics course I. This research was done at Physics Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan. The Collaborative Learning Model is based on a Scientific Approach. There are three subject matters: Kinematics, Dynamics, Effort and Energy. A set of 20 multiple choice questions was used in each cycle as the instrument to measure the student's learning outcomes which had been predictively validated. Based on SPSS 17.0 analysis result, this instrument was declared valid and has had high reliability. For each cycle a pre-test and post-test were implemented. The result shows that there is a significant increase of student learning outcomes for each cycle in respect to the value of normalized gain.

## ABSTRAK

Penelitian ini bertujuan meningkatkan hasil belajar mahasiswa pada perkuliahan Fisika Umum I. Penelitian ini dilaksanakan di Jurusan Fisika FMIPA Univesitas Negeri Medan, dengan jenis penelitian tindakan kelas. Tindakan dilakukan dengan Model Pembelajaran Kolaboratif berbasis Pendekatan Saintifik. Ada tiga siklus dalam penelitian ini, dengan materi pokok kinematika, dinamika, usaha dan energi. Alat pengumpul data adalah instrumen hasil belajar mahasiswa dengan jenis pilihan ganda dan merupakan soal terpilih dari hasil ujicoba terhadap sekelompok mahasiswa pendidikan fisika yang diolah menggunakan aplikasi SPSS 17.0 dengan hasil dinyatakan valid dan memiliki reliabilitas tinggi. Sebelum pelaksanaan tindakan, dilakukan pretes untuk mendapatkan data kemampuan awal mahasiswa. Setelah tindakan selesai pada tiap siklus, selanjutnya dilakukan postes. Hasil penelitian menunjukkan bahwa nilai gain ternormalisasi hasil belajar mahasiswa meningkat setiap siklus. Sehingga dapat disimpulkan terdapat peningkatan hasil belajar mahasiswa pada perkuliahan Fisika Umum I dengan Model Pembelajaran Kolaboratif berbasis Pendekatan Saintifik.

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**Keywords:** Collaborative Learning Model; Class Action Research; Results Learning; Scientific Learning

## INTRODUCTION

General Physics course I is a very important lecture to understand the courses at Physics Major Matematics and Natural Sciences Department, Universitas negeri Medan (Unimed). The success of the students in General Physics course determines their success in advanced physics courses. Therefore, all factors supporting this lecture should be a synergy

to improve student results in General Physics course I.

The preliminary result of the study on General Physics course I showed that students are still lack of the ability to understand the material. It can be seen from the results obtained by students studying in the first semester of 2014/2015 ago, still unsatisfactory that students who received grades A total of 21.8 to 75%, the value of B as much as 71.87 5%, and the value of C as much as 6.25% with the number of 32 students in one class. This situation is due to students' mastery of physics concepts are ge-

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nerally low when they was in high school and learning still has not maximized cognitive abilities of students in solving physics problems so that the results of the General Physics course I is still low. (Panggabean & Irfandi, 2015). From the implementation of basic Mathematics and Natural Sciences (MNS) joint exam for General Physics course I, which is done once a semester at the Faculty of Mathematics and Natural Science (FMNS) Medan State University showed results have not been satisfactory. Values obtained by students between 20-75 scale of 100 (FMNS, 2013). Therefore, it is necessary to improve student learning outcomes through the synergy of all components that support increased student learning outcomes in General Physics course I.

During this time, implemented learning is still limited to one direction i.e. lecture learning, use of the media is rarely used. While the demands of KTSP (Unit Level Curriculum) curriculum and 2013 curriculum mandate learning of *Student Centered Learning*. As a result, students' interest, motivation and learning outcomes become very low and tend to be passive. Therefore, it is necessary to develop a collaborative model that is appropriate to the material characteristics and students characteristics as learners. (Lisiswanti & Oktadoni, 2015)

One of the external factors that can affect the cognitive development of students is a lecturer. This is consistent with that proposed by Slameto (2003), ie, teacher (lecturer) plays an important role in improving the quality of students (students) in the learning and lecturers should really pay attention, think and simultaneously plan the learning process interesting for students, so that students are interested and enthusiastic in learning and willing to be involved in teaching and learning process, so that teaching become effective. In an effort to improve the quality of education, it requires various breakthroughs, both in curriculum development, learning innovation, and fulfillment of educational facilities and infrastructure so that students are interested and challenged to learn.

Addressing the above issues, it is necessary to make efforts for the lecturers using teaching strategies that make students more interested in General Physics I material. One of them is by using collaborative learning. The results of Clark & Baker's (2007) study show that collaborative learning outcomes in diverse groups provide positive results in learning.

Collaborative learning is an inovative

learning which combining various kind of learning models that is be adapted with course material characteristics. Kind of various learning model used are; *first*, the cooperative learning, (Slavin, 2005). A small groups learning model collaboratively with members consist of 4-6 students with heterogeneous structure (Slavin, 2005). Coopertive learning model is characterized by the precence of the task structure, purpose and structure of award which is diferent with an individualistic or competitive learning model. Task structure refers to the way of learning done by students in the classroom (Hollowarni, Erviyenni, Zulhelmi, Herdina, 2008). The goal structure in cooperative learning are called cooperative goal structure, characterized by positive interdependence among students. This means that the success of a student only and if the other students in his group also successfully. (Ibrahim, 2007).

*The second, inquiry learning*. Steps in inquiry learning namely: orientation, define problems, formulate hypotheses, formulating the data, testing hypotheses, and drawing conclusions (Sanjaya, 2009). *Third, the problem-based learning*. According to Arend, problem-based teaching is a learning approach where students work on authentic problems with the purpose of regulating their own knowledge, develop inquiry and thinking skills, develop independence, and confident (Trianto, 2009). *Fourth, Project Based Learning (PJBL)*. According to *Buck Institute for Educaton (BIE)* (Khamdi, 2007) The PJBL is learning model which involve students in problem-solving activity and give opportunities to students work autonomously construct their own learning.

Collaborative learning model above is applied with scientific approach as required by the Ministry of Education (2013) in Permen-dikbud no. 65 of 2013 on education standards with a scientific approach. Through scientific approach students are trained to be able to think logically, in sequence and systematically using higher level thinking capacity (*high order thinking*) (Sudrajat, 2008)

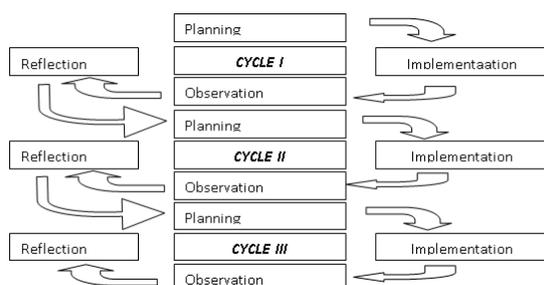
Specifically Mitnik, Recabarren, Nussbaum, and Soto (2009), describes the collaborative learning based on the model with the knowledge can be created in a population with members actively interact by sharing experience and take the role of asymmetry (different). In other words, collaborative learning refers to environment and methodology activities of students performing common tasks in which each individual depends on and is responsible for

one another through conversations with face-to-face (Chiu, 2008). Based on theory, that the application of collaborative learning based on scientific approach at General Physics course I can improve student learning outcomes on Physical Education Program. This research aimed to improve students learning outcomes on General Physics course 1.

## METHOD

This research was conducted at the Department of Physics Medan State University in the first semester of the academic year 2016/2017. The samples in this study were all students of physical education courses in grade A class of 2016 took a General Physics I courses.

This research is a type of class action, which lasted for three cycles and the plot is done by adapting the flow of classroom action research (Kemmis, Taggart & Nixon, 2014) The flow of this research as in Figure 1



**Figure 1.** Action Research Cycle (adapted from Kemmis, et al., 2014).

In this study, there are three cycles with each cycle consisting of the stages of planning, implementation, observation and reflection with the following description.

### Planning

In the planning stage, the researchers held several meetings to discuss technical implementation of classroom action research, recorded and identified the contents of text books in all the libraries in Medan State University which can be used to support the course of General Physics I, made questionnaires or observation formats, made media of learning, made lesson plan in accordance with learning innovation that will be used in this research.

### Action

At this stage, the researchers taught General Physics I courses to students by imple-

menting a collaborative learning model (cooperative learning, *inquiry* learning, problem-based learning, project-based learning) and using the library as a reference source. The lecture is integrated with the adoption of practices directly related to General Physics I lecture material that is being discussed with the scientific approach.

### Observations

Observations made by researchers in the classroom during teaching and learning activities take place. Observations were made to the results of students learning both during face to face and the things that happened during the learning process and group discussion. The number of observer in each meeting amounted to one person. The instruments used were observation sheet format developed by stages in the scientific approach and indicators in accordance with the competence General Physics course I to be achieved.

### Reflection

Before doing reflection, data obtained through observation student results, is analyzed to obtain an overview of the implementation of each cycle. The results of this analysis are used for improvement in the next cycle. Reflection is done based on the results of observational data analysis conducted. The result of data analysis is an ingredient in determining corrective action for planning phase in the next cycle. In a reflection activity studied the link between observations with the implementation of collaborative learning in each cycle, and to describe the development of each cycle progress made, obstacles encountered, and mitigation efforts in the next cycle.

As for how to perform data analysis of learning outcomes during the course of General Physics I of the observation sheet for each cycle by adding up the scores obtained for each learning outcome then the total score was converted into a percentage with assessment criteria:

Very good	= 85% - 100%
Good	= 75% - 84%
Pretty good	= 65% - 74%
Not good	= ≤ 64%

Improved student learning outcomes is calculated using the Gain Ternormalisasi (Hake, 2007)

$$g = \frac{(\text{posttest score} - \text{pretes score})}{(\text{maximum score} - \text{pretes score})}$$

**RESULTS AND DISCUSSION**

This study begins with the implementation of the pre-test using test instruments, each of it consists of 20 multiple choice questions on the subject matter of kinematics, dynamics, work and energy. Giving pretest aims to obtain preliminary information about the ability of students physical education grade A class of 2016 before implementation of collaborative learning. The results of the pretest in the subject matter of kinematics, dynamics, work and energy will be compared with the results of post-test at the end of learning to get information about the impact of collaborative learning implementation which is applied to General Physics course I with the subject matter of kinematics, dynamics, and the effort and energy on every cycle. After the learning completed, it has done post-testes to get data result of action implementation. The pre-test and post-test results obtained in the subject matter of kinematics, dynamics, work and energy as shown in Table 1.

From Table 1 can be seen that the average student results before action is still very low in the material kinematics, dynamics, work and energy. It is necessary for doing action to improve the achievement of student results on the material kinematics, dynamics, work and energy by applying a scientific approach based collaborative learning.

**Cycle I**

Actions taken in the first cycle consists of two sessions, the first meeting of the submateri motion in one dimension and the second meeting of motion in two dimensions. Lecture activities in cycle I is done in accordance with the unit of lecture I and unit of lecture II. Class begins with the delivery of learning objectives, so that students know the competencies to be achieved in the learning process and given the opportunity to work on the issue of selection physics contained in the modules in groups outside of lecture hours associated with the

material to be covered for presented during lectures take place.

Implementation of learning by using this leaarning is emphasized on efforts to make students active in answering questions and express opinions. This is done in an effort to improve student results in the course of General Physics I. The learning steps of each cycle as a whole include: 1). Delivering purpose and motivation of students. 2). Delivering presentation of information in the form of demonstrations or through reading materials. Students activities observed demonstration of irregular straight motion object (ISM) to identify physical quantities contained in the objects that perform MSCR. Furthermore, students are asked to create and ask questions about the information that has not been understood so happened debriefing and discussion. 3). Organizing students into groups. Students were divided into six groups to do RSM (regular straight motion) experiment and ISM (irregular straight motion). From this activity the students collect data of experimental results conducted. 4) Guiding group work and study. At this step, students processed and analyzed data have been obtained from experiments and associate the phenomena that can be seen from the experiment of RSM (regular straight motion) and ISM (irregular straight motion) then make a conclusion from the results obtained. In addition to processing experimental data, students are also given the physics issues to be solved in their groups. 5). Assessment of what has been learned so that each group presented their work. In this section, students' group communicate the results of their work using the projector in front of the class. 6). Give appreciation both in groups and individuals. After all groups present the results obtained, the lecturer announces the group with the best results and performance. The best group is given praise and appreciation in the form of additional value. At the end of the meeting in first cycle, students are given the test on kinematics mate-

**Table 1.** Results of pre-test and post-test

	Kinematics		Dynamics		Effort & Energy	
	Pre-tes	Post-tes	Pre-tes	Post-tes	Pre-tes	Post-tes
Mean	37.08	73,33	38.13	76.88	38.75	82,71
Std. Deviation	6,903	7,173	5,863	6.395	6,124	5,894
Variance	47,645	51,449	34.375	40,897	37,500	34.737
Minimum	25	60	30	65	30	70
Maximum	50	85	50	90	50	95

rial consisting of 20 multiple choice questions to determine students' mastery of material has discussed. Students' Minimum Completeness Criteria that must be achieved from the implementation of the test is i.e minimum grade of graduation that must be obtained by students applied in Medan State University.

Then post-tes result in the first cycle is compared with the results obtained on pre-test before the action undertaken to obtain data increase student learning outcomes are achieved by calculating the value of *Gain* Ternormalisasi (Hake, 2007)

### Cycle Reflection I

Based on post-tes 1 result in the first cycle, the average value of student results on the first post-test gain is 73.33 and student learning outcomes have been increased in the medium category with a value of 0.57. However, from the observation of the research team to the students when the lecture has not been as expected because the students have not been fully active when the lecture took place. This can be seen from the fact that some groups can not present in front of the class because the group does not solve the physics problem that belongs to the group. In addition, in some groups also seen the domination by one person from the members of his group while the other members are still hesitant and do not dare to appear in front of the class or comment on the matter raised. Therefore, the provision of action still needs to be done and it has expected that the results in cycle II not only there is an increase in learning outcomes but also student activeness during the lecture also increased from before. The obstacles encountered in the implementation of the learning process in cycle I and it should be improved on the next action are: overall students are not confident to present the results of the completion of the group and still less daring in asking questions, students are still not entirely active in the discussion group both in participation to solve problems, give answers and give opinions. To overcome the obstacles in the first cycle and to improve student learning outcomes, it is necessary to continue on the second cycle by improving student activity by researcher giving motivations and awards both in the form of praise and additional value to the students to stimulate courage and student confidence.

### Cycle II

Action implementation on the second

cycle consists of two meetings. The first meeting encounter of submission of Newton's laws of motion and styles. While second meeting on Newton's laws application. Similarly, in cycle I, in cycle II begins with the delivery of learning objectives, so that students know the competencies to be achieved in the learning process and given the opportunity to work out physics problems in groups outside the class hours related to the material that will be discussed to be presented at the time of lectures take place.

Implementation of action performed in cycle II is a continuation of cycle I. The learning steps in cycle II are generally the same as the learning steps in cycle I. The only difference being the subject matter discussed, namely Dynamics and make improvements to things that are still not good in the first cycle were obtained based on the reflection of the action on the first cycle to be increased in the second cycle.

The action done on the second cycle, the researchers provide an explanation of the scope of dynamics. Furthermore, students who had been in each group were directed to conduct experiments and discuss Newton's Law up the issue of the dynamics in the group, then presented the results of experimental data analysis and solving problem of dynamics. Students are motivated to actively participate in the learning process. Students are also requested in turn to present the results of the troubleshooting that has been created, ask questions, opinions, and evaluate problem-solving group that is being performed.

After the action is completed, at the end of the meeting, researcher given post-tes of dynamic materials to obtain information on the impact of the implementation of the action using a collaborative learning model based on a scientific approach. Based on Table 1 students' average results increased from the first cycle in the amount of 73.33 into 76.88 in the cycle II. Further improvement of student learning outcomes achieved in the cycle II is calculated using the normalized gain. From the calculation of the gain value learning outcomes of each student, then it is performed calculating an average gain value of 0.62. This value has an increase of 0.05 of the cycle I.

### Cycle II Reflection

Based on the result of post-tes 2 in cycle II, the average score of the class of 76,88 and the gain value of the students learning achievement increase from the value in cycle I although still in the medium category. Lecture

atmosphere is also more active when compared to cycle I. This is evident from researchers observation, overall students in the groups have had the courage to present the results of their work even though the results have not been right. This shows that students have been able to demonstrate the fifth step in the scientific approach of communicating. However, from the observation of the research team to the students on the lecture, there are some students who hesitate to comment and give opinions. To dispel doubts on some students then the researchers feel the need to continue giving the next action in cycle III, in the hope that students who are still in doubt will arise their confidence to give their opinion.

### **Cycle III**

Implementation of action in cycle III consists of 1 meeting with material Effort, Energy, and Power. Similarly, in cycle I and II, in cycle III begins with the delivery of learning objectives, so that students know the competence to be achieved in the learning process and given the opportunity to work on physics problems in groups outside the hours of the course related to the material that will be discussed to be presented at the courses. Implementation of action carried out in cycle III is a continuation of cycle II. The learning steps in cycle III are generally the same as the learning steps in cycle I and II. What distinguishes only on the subject matter discussed is Effort and Energy and make improvements to the things that are still not good in cycle II obtained based on the reflection results of action in cycle II to be increased in cycle III.

The action done on the third cycle, the researchers provide an explanation of the scope of effort materials, energy and power. Furthermore, students who have been in their groups are directed to present problem solving related to the material being discussed. Students are motivated by researchers to actively participate in the learning process especially in giving opinions. Students are also asked in turn to present the completed problem solving results, ask questions, opinions, and evaluate the problem solving of the group that is performing. Once the action is completed, at the end of the meeting, the researcher given postes on effort and energy materials to get the information the impact of implementation using collaborative learning model based on a scientific approach.

From Table 1, students average results increased compared to cycle II in the amount of 76.88 into 82.71 in cycle III. This means that

the action given in cycle III has been able to improve student learning outcomes better than the previous cycle. Then, improvement of learning outcomes achieved by students calculated using normalized gain. From the calculation of the gain value learning outcomes of each student then it is calculated average gain of 0.72 higher category. When compared with the average gain value in cycle II of 0.62, the average gain value of cycle III shows an increase of 0.10 from the previous cycle.

### **Cycle Reflection III**

Based on the evaluation conducted through post-tes 3, students' learning outcomes have improved as expected. Through the results of competency tests III analysis and researchers observation in the third cycle obtained the results that actions taken on this cycle has been successful in increasing student activity and learning outcomes by scientific approach. From the observations made by the researcher it is seen that all the students have been active in the lecture. Student activity continues to increase when compared from cycle I, cycle II until cycle III. In addition, the improvement is also seen in student learning outcomes that have successfully reached the established students' Minimum Completeness Criteria. From the results of the cycle III test obtained the average value of student learning outcomes 82.71 and entirely get the value  $\geq 70$ . In cycle III the gain value also increased from cycle II to 0.72 with high category.

From the three post-test data analysis of pre-test data can be displayed students data gain normalized results on the course of General Physics I as in Table 2. Table 2 shows the improvement of student learning outcomes at the course General Physics I with the subject matter of kinematics, dynamics, effort and energy.

Based on the results of data analysis showed that the implementation of collaborative learning model with the scientific approach has improved students learning outcomes in the course of General Physics I. Improved student learning outcomes at the course General Physics I happen due to collaborative learning has six characteristics, namely (1) the team share the task to achieve the learning objectives, (2) among team members give inputs to better understand the problems encountered, (3) team members ask each other for more in-depth understanding, (4) each team member empowers the other to speak and provide in-

**Table 2.** Increased Learning Results of Cycle I, II, and III

	Kinematics		Dynamics		Effort & Energy	
	Pre-tes	Post-tes	Pre-tes	Post-tes	Pre-tes	Post-tes
Mean	37.08	73,33	38.13	76.88	38.75	82,71
Gain	0.57		0.62		0.72	
Interpretation	Medium		Medium		High	

put, (5) teamwork accountable to others, and accountable to themselves, and (6) among team members there is interdependence (Myers, 1991). Collaborative learning activities vary widely, but the overall focus is on the exploration of learners, rather than simple educational explanations or detailed explanations (Smith & Mac Gregor, 1992).

Collaborative learning is done based on a scientific approach. Lecture activities conducted through the process of observing, asking, trying/collect data, associate/reasoning, and communicating through group presentation in front of the class. These things have positive impact on the improvement of students' abilities and skills ranging from dare to ask, dare to express opinions, and confidence in presenting the results of the group.

Collaborative learning application using cooperative model in the learning process can cause the effect of increasing students participation in the class (Herrmann, 2013) and they can communicate their arguments. From perspective of constructivist learning, dialogue and argument are valuable learning opportunities for students (Biggs & Tang, 2011; Pritchard & Woollard, 2010), and from this perspective, the interventions carried out in part successful.

Cooperative learning is suitable for applying the principles of KKN curriculum implementation since if it is seen the impact of learning as a whole is to increase the students confidence and think more critically where Slavin (2005), Davidson & Worsham (1992), have proved their research that the positive impact of learning cooperative learning are : (1) achievement of learning outcomes that can be accounted for, (2) develop a high mindset, (3) develop student self-confidence, (4) improve inter-group relationships, (5) develop student social skills, (6) accept the perspective of others. Cooperative learning often interpreted as part of a collaborative *learning*.

Furthermore, other learning improving student learning outcomes at the course General Physics I is giving project task through Project Based Learning. Project-Based Learning

is designed to be used on complex issues that learners need in investigating and understanding it. Project-Based Learning provides students with the opportunity to explore material using various means that are meaningful to themselves, and conduct collaborative experiments.

Inquiry learning through the completion of the questions contained in the module General Physics I and that presents a problem-based learning contextual issues that stimulate students to develop skills / creativity of high-level thinking (HOTS). This is because the problem-based learning model has several advantages such as that stated by Riyanto (2010), among others: (1) Students better understand the concepts taught because they themselves find the concept. (2) Demand high-order thinking skills to solve problems. (3) Knowledge is embedded based on schemata owned by students so that learning is more meaningful. (4) Students can feel the benefits of learning because the problems studied are the problems encountered in real life. (5) Making students become more independent and more mature, motivated, able to give aspirations and accept other people's opinions, inculcate positive social attitude among students. (6) Conditioning students in learning groups that interact with each other, both with lecturers and friends will facilitate students achieve learning mastery. The results of Panggabean, DD and Irfandi (2015) study shows enhancement in learning outcomes and student learning outcomes. Problem-based learning is learning that challenges students to "learn how to learn", to work in groups to seek solutions to real-world problems.

With the adoption of several learning models such as inquiry learning, project-based learning, cooperative learning as a form of learning innovation in the form of collaborative learning then the lecturers only have directive authority or manager to learn, on the contrary, it was students who need to be more active. In collaborative situations, students interact with empathy, respect, and accept the weakness or strengths of each others. In this way will grow

a sense of security, allowing the students to face various changes and demands of learning together. This is ultimately a positive impact in improving the learning outcomes of students, so that it can be concluded there was an increase learning outcomes of students in the course of General Physics I with collaborative learning model based on a scientific approach.

### CONCLUSION

Based on the results of the study concluded that the Model Collaborative Learning based Scientific Approach improves the student learning outcomes in the course of General Physics I, with its subjects are Kinematics, Dynamics, Effort and Energy . Learning outcome can be seen from the average gain of students results that have an increasing in medium category of cycle I and II, and a high category in the third cycle .

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# VIRTUAL LABORATORY OF ELECTRICITY CONCEPT TO IMPROVE PROSPECTIVE PHYSICS TEACHERS' CREATIVITY

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## ABSTRACT

A virtual laboratory for electrical materials has been developed in this study. The virtual laboratory was developed as an alternative laboratory due to the limited equipment of physics experiments and simultaneously assisting students in visualizing abstract concepts in physics. This article discusses the results of testing on the effects of virtual laboratories on improving the creativity of prospective physics teachers. Measurable creativity includes verbal and figural creativity. The model testing process uses the quasi-experimental method. The participant of this research is prospective physics teachers in Faculty of Teacher Training and Education, University of Mataram. The research instrument used in the form of tests of verbal and figural creativity related to the electrical material being studied. The results showed that there is a difference in the improvement of prospective physics teachers' creativity after learning in both groups. In general, the increase in creativity in the experimental group is higher than the control group. The increase in verbal and figural creativity of the two groups also differed significantly. In both groups, the increase of verbal creativity is higher than that of figural creativity. This suggested that the developed virtual lab model proved to enhance the creativity of prospective physics teachers.

## ABSTRAK

Dalam penelitian ini telah dikembangkan laboratorium virtual untuk materi listrik. Laboratorium virtual dikembangkan sebagai alternatif terbatasnya peralatan eksperimen fisika dan membantu visualisasi pada berbagai konsep abstrak dalam fisika. Artikel ini membahas hasil pengujian pengaruh laboratorium virtual terhadap peningkatan kreativitas calon guru fisika. Kreativitas yang diukur meliputi kreativitas verbal dan figural. Pengujian model menggunakan metode kuasi eksperimen. Subjek penelitian ini adalah mahasiswa calon guru fisika di FKIP Universitas Mataram. Instrumen penelitian yang digunakan berupa tes kreativitas verbal dan figural yang terkait dengan materi listrik yang dipelajari. Hasil penelitian menunjukkan adanya perbedaan peningkatan kreativitas calon guru fisika setelah pembelajaran pada kedua kelas. Secara umum, peningkatan kreativitas pada kelas eksperimen lebih tinggi dibandingkan kelas kontrol. Peningkatan kreativitas verbal maupun figural pada kedua kelas juga berbeda secara signifikan. Pada kedua kelas, peningkatan kreativitas verbal lebih tinggi dibandingkan kreativitas figural. Hal ini menunjukkan bahwa model laboratorium virtual yang dikembangkan terbukti dapat meningkatkan kreativitas calon guru fisika.

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**Keywords:** Electricity concept; Prospective teachers' creativity; Virtual laboratory

## INTRODUCTION

Laboratory activities are important component in physics learning. Through laboratory activities aspects of processes, products,

and scientific attitudes can be improved. In the teaching of physics it have an important role, among others, as a vehicle for: (1) developing basic skills of observing or measuring and other process skills such as taking notes, creating tables, graphs, analyzing data, drawing Conclusion, communication, and teamworking; (2) proving the concept or laws of nature so as

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to further clarify the concept which has been discussed previously; (3) developing thinking skills through problem-solving processes in order to help students find their own concepts. It means that the laboratory has been used as a vehicle for learning how to learn (Wiyanto, 2008).

In experimental activities in the laboratory, students can also develop academic and social skills. Through this activity students can improve the mastery of concepts, develop learning skills, conduct their own experiments, and develop a variety of scientific skills. From a social point of view, learners will be accustomed to appreciate the opinions of others, learn to communicate ideas, and work together on teams.

One of the factors that affect the success of laboratory activities is the availability of resources, including materials and equipment, space and furniture, laboratory staff, and technicians. The availability of adequate resources will obviously support the implementation of laboratory activities, on the contrary the limitations of tools and materials will lead to the ineffectiveness of laboratory experiments.

The result of observation of availability of supporting facilities and laboratory activities in some teacher education in West Nusa Tenggara shows that physics experiment activity can not be done due to inadequate equipment. Generally available tools are limited in number compared to the ratio of students who will use them, while some advanced experimental support tools are not available at all. This will certainly have implications for the learning process. In the framework of expansion, equity of quality and access to education, it is necessary to consider solutions that enable laboratory activities to be carried out to support the physical learning process as it should be implemented.

The development of information technology provides an opportunity to build and use computer animation for learning oriented to microscopic representations. This fact is then the starting point of the emergence of new innovations in physics learning. One of them is the use of computer technology, both in the process of learning and experimental activities virtually. A computer simulation that allows important functions of laboratory experiments to be performed on a computer is called a virtual laboratory. In general, virtual laboratories are intended to transfer knowledge both conceptually and procedurally. In the implementation,

it is necessary to give initial knowledge to the students about how the experiment should be done.

Chen, Song & Zhang (2010) define a virtual laboratory as software for simulating a laboratory environment. Ciepiela et al. (2010) has stated that the key concept of a virtual laboratory is an experiment. Experiments are processes that combine data with a series of activities to get experimental results. Virtual experiments are complex workflows, execution of recurring instructions from programs installed on the computer.

Under the definition, virtual labs are not considered as substitutes or competitors for real laboratories, but rather as extensions to new opportunities that are unrealized in real and affordable laboratories. One of the principles of defining virtual labs is that virtual laboratories are not defined as learning units but rather learning space for virtual experiments. It is important to remind that lecturers still have to explain the learning objectives to the students.

Digital computers are an important tool for investigation in scientific research. Computer simulations are not intended to replace real laboratory equipment. All students in the laboratory should have the opportunity to gain confidence in their ability to solve problems and explore with mechanical, thermal, optical and electrical systems. Using a virtual laboratory, students have the opportunity to apply scientific methods with complete accuracy for every phenomenon they face (Harms, 2000).

The virtual laboratory must provide sufficient discretion for individual experiments or experiments beyond the limits set by the curriculum. The use of virtual labs in various learning models has been able to improve the mastery of physics concepts. Nisrina et al. (2016) found that the use of virtual laboratories in cooperative learning models can improve the mastery of physics concepts. Other researchers have also tried to use virtual laboratories in physics learning with different learning models, for example Sugiana et al. (2016) using laboratories in generative learning models on impulse momentum materials; Sari et al. (2016) who use virtual labs in discovery learning models in dynamic electrical materials; and Kusdiastuti et al. (2016) who use it in an inquiry model on optical materials. These studies have proved to have a significant effect on the use of virtual laboratories to increase the mastery of students' physics concepts.

Virtual lab-assisted learning is expected

to enhance the creativity of prospective physics teachers. Mishra (2012) explains that in the last few decades, digital technology has contributed to the development of creativity. According to Harding (2010), creative action is essential for the advancement of civil society. Thus, teaching students to think creatively is very useful for them to be skilled and tough in the future. Rawat et al. (2012) had stated that creativity is the main goal of education worldwide.

It is important to equip physics teacher candidates to think creatively so that they can be creative teachers, teach and equip creativity to the students. Creativity is needed to enable them to act creatively and excel in global competition. According to Wu et al. (2014) creative talent is the foundation of a nation's competitive advantage and university is the main core for fostering such creative talents.

Jackson (2006) stated that creativity is a fundamental characteristic of human being which is the center of prosperity, productivity and prosperity of a nation. However, the existence of this creative character in higher education seems almost unacknowledged. Creativity arises spontaneously through the relationship and interaction of lecturers with their students in very specific and challenging situations. Whereas Jackson et al. (2012) defines creativity as a mental process involving the development of new ideas or concepts, or new relationships with existing ideas or concepts. From a scientific point of view, the product of creative thinking is usually considered to have originality and conformity. Creativity is unique among scientific phenomena that can not be defined with only one definition. Aqda, Hamidi & Rahimi (2011) considers creativity as one of the extraordinary characteristics of human beings. The development of creative strategies such as brainstorming and problem solving whose general purpose is to provide the environment in generating ideas. Creativity is an innate talent and attaches to every human being

Most researchers who cultivate about creativity generally recognize that creativity is not synonymous with intelligence (Runco, 2004). However, creativity demands an extraordinary resource of knowledge and domain relevant to skills (Mumford et al., 2009). There is a general consensus of creativity researchers who claim that creativity is a complex process in which interactive relationships lie in four dimensions: creative people, cognitive processes of creativity, product of creative performance, and social and cultural contexts (Batey & Furnham, 2006;

Zimmerman, 2009).

Creativity is a complex process of relationships between people, processes, products, and the socio-cultural context relevant to the knowledge domain. People who are not creative in the general sense, sometimes they are creative in certain domains such as visual arts. Creativity can be developed through learning. In the concept of creativity should be considered that all learners have the ability to be creative (Zimmerman, 2010).

Rawat et al. (2012) stated that a creative person is a person who is able to judge accurately in putting facts into ideas, selecting and elaborating ideas. A child cannot learn this art unless it is taught, and is allowed to go through the process as it should. In his research, Garaigordobil (2006) gave treatment to stimulate the four types of creativity: verbal, graphic-figural, constructive, and dramatic creativity. Other researchers O'Reilly et al. (2001) described creativity in verbal and figural groups. Verbal creativity can be grouped in indicators of originality, flexibility, fluency while figural creativity can be grouped in originality, elaboration. On the other hand Preckel et al. (2006) states that creativity can also be grouped into verbal, figural, and numerical creativity.

One's creativity cannot develop automatically by itself, but requires the stimulation of the environment. To develop the creative potential of an individual, an external driving force is required in a situation that supports the potential within the individual. Kandiko (2012) explains that in order to support and enhance creativity, it can start by exploring how the relationship between sciences that has many features such as creativity to be further understood and taught in higher education. In perspective, creativity can be developed; learning and the results reflect something new and valuable. However, most creative works have a meaning to be directly involved. This indicates that a change in the teacher education pattern is required. This is useful for helping prospective teachers to have an understanding of (1) what creativity is required; (2) how to recognize student work; (3) the types of tasks that can foster creativity; (4) creative pedagogy (Wyse & Ferrari, 2015).

The importance of providing creativity for prospective teachers raises new innovations by each teacher to prepare future and creative teachers who are able to compete. The development of a virtual lab model is one of the limited alternatives of physics experimental equipment that can be used to equip the creativity of

physics teacher candidates. Creativity can be developed from exercises or lessons created by lecturers together with students in a creative learning environment. Bricken & Byrne (1993) revealed that virtual media is a very interesting creative environment to teach and learn.

Stages in learning by using a virtual laboratory encourage the increase creativity. The introduction stage serves to introduce the virtual laboratory, functionality features, to its use. The activity continued with brainstorming through discussions related to conceptual design between lecturers and students. This discussion activity can improve students' verbal creativity. The next stage is the decision making stage which means the decision making process to make and do something. Students then proceed to the demonstration stage of doing and making something to include, demonstrating the ability to develop modeling and then building the things that are gained from the virtual world. Students then do technical detail or check and collect data, as well as obstacles encountered with the object identified in writing. In the final stages of exploring the students are asked to build a relationship between the information obtained with relevant knowledge then actively participate in class discussions.

Herga & Dinevski (2012) explains that virtual labs open up a whole new world of creativity in learning. This is in line with the opinion of Oidovet al. (2012) which states that the animation that is in the virtual lab can be used as an ideal demonstration tool to present an event. In accordance with the stages of virtual laboratory usage in the period of demonstrate, students can actively and creatively use the tool towards meaningful experimental results. The activity will have an impact on creativity in understanding the theoretical and practical aspects based on virtual experiments performed. Based on this, this study is intended to obtain the results of empirical testing on the effect of the application of virtual laboratory models on electrical materials that have been developed on the creativity of prospective physics teachers.

## METHOD

This research has successfully developed a virtual laboratory model on electrical concept. This research consists of three stages, namely preliminary study stage, design development stage, and model testing stage. In the model testing phase, the method used is quasi

experimental research. The sample of this research is physics teacher education student in Mataram which are divided into two groups, experiment and control. The experimental group is taught with virtual electric lab assisted learning, while the other group is a control group taught conventionally. Conventional learning uses direct instruction model. The study was conducted for 6 meetings. Each meeting is held for 2 x 50 minutes.

The research instrument used is a test of creativity in the form of essay test. The test consists of two parts: a verbal creativity test and a figural creativity test. The verbal creativity test related to the ability to compose words, sentences, and explanations that are relevant to the concept. The figural creativity test related to the ability to create an image, complete it, or create a series relevant to the electrical concept. The verbal and figural verbal creativity tests are related to electrical material that has been studied in both groups. Data were analyzed by using appropriate statistical tests using SPSS version 20 software aid.

Enhancement of student creativity is determined from normalized gain scores (N-gain). This is intended to avoid errors in the interpretation of individual gain scores. To obtain an N-gain score, the following equations are used (Cheng et al., 2004).

$$N - gain = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} \times 100\%$$

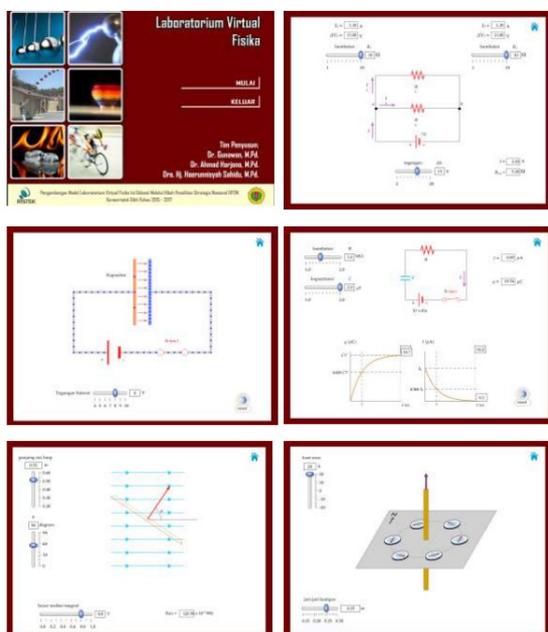
Where N-gain > 70% (high);  $30\% \leq N-gain \leq 70\%$  (moderate); and N-gain < 30% (poor).

In this research, empirical testing stage has been done to find out the advantages of virtual lab model to develop creativity of physics teacher candidate. Figure 1 shows some examples of virtual experiments on electrical concepts that have been developed.

The virtual laboratories have been developed in the form of interactive simulations that can be used to conduct virtual physics experiments by students on the material being studied. There are a total of 41 virtual experiments developed in this study.

The virtual laboratories used have been validated in advance on aspects of physical content as well as on aspects of media and technology used. Some substantial improvements have been made to the refinement of the program before it is used in extensive trials for measuring the advantages of virtual lab models on the creativity of prospective physics teach-

ers, both verbal and figural. In extensive trials students of physics teacher candidates are divided into two groups, namely experiment and control group.



**Figure 1.** Some Examples of Electrical Virtual Laboratory

At the beginning of the program there is information about programs, research teams, and sponsors for program development. The next view is the program menu according to the material being studied. The program is focused on virtual experimentation activities so that physics material is not included in it. The design principles are adapted to the design principles and theories of multimedia cognitive, not too much text, as well as navigation systems associated with the subject structure that students are studying. Gunawan et al. (2016) revealed that this kind of design principle will help students to focus to understand what is shown in the program so that mastery of physics concepts learned to be better, especially students with visual learning style.

In its use, the student is allowed to use any textbook as long as it is related to the material being studied. Users are given the discretion to change a variable and see its influence directly to other variables. In this virtual laboratory assisted learning the students work independently by exploring the features freely for the achievement of learning objectives.

Setting these goals is important for the ease of measuring the success of creative learning. According to Shaheen (2010), the ed-

ucational process needs to set goals, so that the creativity developed encourages that organized education has benefits to the community. Among the characteristics that must be trained on learners is learning how to do something creatively. Features and menus prepared in virtual labs allow participants the freedom to use their imaginations freely. Students are allowed to make plans and stages that they find easier to understand a concept. This virtual laboratory is accompanied by a student worksheet that contains a number of open questions and encourages students to respond with possible answers to a problem.

According to Horng et al. (2005), one of the goals of creative learning is the creation of a learning environment in which the imagination of learners is permitted and free from unnecessary regulations. Creative learning activities are centered on learner; there are multimedia aids, classroom management, material delivered in conjunction with real life, and open questions and encouragement for creative thinking.

The same opinion was expressed by Jackson (2006) which shows that creativity should involve students with questions and challenges; Create and see relationships; Consider what is possible; Explore ideas and options to stay open; And reflects a critical attitude to ideas, actions and outcomes. Toivanen et al. (2013) states that creativity always depends on the environment. Creativity does not occur in isolated or closed circumstances. Adams et al. (2007) stated that creativity is a skill that must be trained and equipped to students through the appropriate environment and using effective practice. This exercise should encourage creative thinking by having multiple divergent solutions. It is also recommended to use open-ended questions, where students must define what they need to solve the problem.

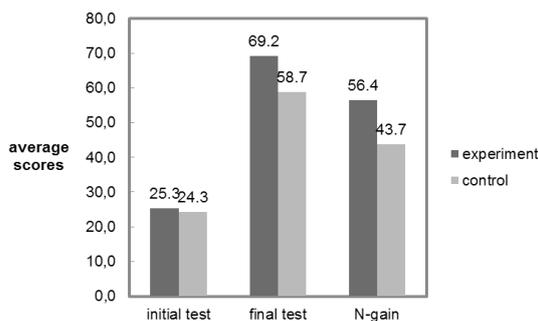
In virtual lab assisted learning, students learn not only physics using software but they can train many things including computer skills, scientific attitude, and cooperation. This is in accordance with the opinion of Black & Browning (2011) which states that in digital art, students' understanding is also through the act of creating something as a form of self-expression, so they do not just learn new software. Zampetakis et al. (2007) also stressed that in an effort to train creativity, it should not only on the element of skills, but also attitudes, motivations, and self-image.

Virtual lab-assisted learning in the classroom can be divided into four stages in accor-

dance with the time allocation, which is introduction, brainstorming, design, and share. At the introduction stage each student is introduced to the program and the learning objectives to be implemented. Students are given guidance and explanation of the function of each feature, menu, including test to be performed. This period should be made efficient, concise and clear. At the brainstorming stage each student identifies the experimental design criteria and constraints, writes the design plan, including identifying what data needs to be taken and compared. Brainstorming is the technique of individual or group creativity to find the conclusions of a particular problem by compiling a list of spontaneous ideas submitted by each member of his group. In the design phase students design and test the design of virtual experiments developed. Each data obtained is written on the worksheet. At the share stage, students present the experimental results and participate actively in class discussions.

### Students' Creativity after Learning

In the learning of electrical concept in both groups, the data have been obtained related to the creativity of physics teacher candidates, either from the initial test, the final test, and the N-gain. The following describes the results of the measurement of creativity after the electrical concept of learning. Figure 2 shows the average comparison of creativity test scores on initial, final, and N-gain tests.



**Figure 2.** Comparison of Creativity Test Results of Both Groups

From Figure 2 it can be seen that the initial ability of the two groups is almost the same, indicating the average test results in both groups as well as the homogeneity test results that have been implemented. From the final test data and N-gain can be obtained information on the increase in both groups. The increase is in the medium category. This enhancement

of creativity is a positive influence of the virtual lab that has been developed. Characteristics of programs that provide flexibility in choosing features and determining stages according to the concept learned encourage the creativity of each student. In this learning program, there is discussion between students and lecturers with students. There are also sessions when students reflect on the satisfaction of the discovery of important concepts learned. The program facilitated group co-operation at a particular session to discuss the results of its virtual experiment.

Garaigordobil (2006) stated that there is a relevant role of social and affective factors in the development of creativity. In particular, they underline the positive effects of shared play, communication, and emotional expression for the development of creativity. This is consistent with the results of Gunawan & Liliasari (2012) study which found that experimental class study students supported by appropriate virtual experiments have greater open-mindedness than control-class students who only hear information without being able to prove the truth of the theory through experiment.

A virtual laboratory for some students is also considered a fun game, as they can try and learn to make predictions that are further proved themselves. Put simply, it helps reduce the difficulty and tension in physics learning that is generally felt by some students while studying physics. This is in line with the results of research Byron, Khazanachi & Nazarian (2010) who found the influence of stress on creative performance more complex than ever. Although, it still needs to do further researches at the stage and under what conditions stress which affects creativity. Other research conducted by Garaigordobil (2006) also shows that creative-cooperative game-based intervention programs can foster an increase in verbal and figural creativity. The results of Jackson et al. (2012) revealed that playing video games predicts all the steps of creativity. Regardless of gender or race, video game playfulness is associated with greater creativity.

One experimental study found a causal link between playing video games with visual-spatial skills in adults (Green & Bavelier, 2007). Even with more stringent criteria, there is a correlation between playing video games with every significant and positive creativity measurement. Aqda et al. (2011) have identified factors that can enhance creativity, such as letting students experience without limiting them

to specific situations, giving them opportunities for self-improvement and learning to discover, respect individual differences of learners, and provide models of creative behavior patterns to follow.

Some of the interactive experiments contained in the learning model provide a great opportunity for students to learn in estimating and to try their own to prove the truth of their estimates. The proven estimates that students have made can motivate students to learn more. If the student's estimates are not precise, the student can immediately predict the probable cause, and then correct it so that the final conclusion is made more precise. The task challenge and the experimental design project provided in the lessons also encourage student creativity. This is in line with the results of Suranti et al. (2016) who found that project assignments in virtual media-assisted learning models helped learners improve their ability to learn physics better than other conventionally-learned learners.

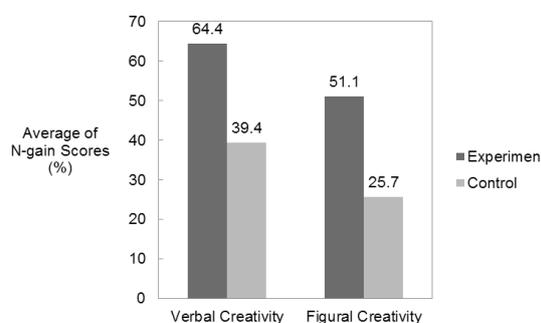
### Comparison of Verbal and Figural Creativity in Both Groups

In addition to creativity data in general, this study also compares the improvement in every aspect of creativity after learning electrical concepts in both groups. A comparison of the improved verbal and figural aspects after learning in both groups is shown in Figure 3.

Based on Figure 3 it can be seen that the increase in verbal creativity is higher than the increase in figural creativity in both groups. Enhancement of creativity in both groups was in moderate category, except the increase of figural creativity in the control group which was still in the low category of 25.7%. In a comprehensive analysis of the analytic factors of intellectual ability it can be found that the verbal ability is known to have a higher effect on the idea than the fluidity or flexibility. The results of this study are consistent with the results of O'Reilly et al. (2001) who found that the results of verbal creativity measurements were higher than figural in both groups, particularly on indicators of originality.

In Preckel et al. (2006) it is found a positive correlation between intelligence and creativity. The strongest correlation exists in verbal creativity. In his research Garaigordobil (2006) also found a significant positive influence of treatment in improving verbal and figural creativity. In this program verbal creativity is increased on three indicators, namely fluency, flexibility, and

originality. Smoothness is related to the ability to generate many ideas; flexibility is concerned with proficiency in change from one approach to another or from a certain way of thinking to another; whereas originality is concerned with the capacity to bring new or more acceptable ideas or solutions.



**Figure 3.** Comparison of Verbal and Figural Creativity in Both Groups

Although the increase of verbal creativity is higher than that of figural creativity, the difference in higher increase actually occurs in figural creativity. From the data obtained can be found there is 13.3% difference in verbal, 13.7% in figural. Increased verbal creativity in both groups was in the moderate category, whereas the improvement of creatural figural of the control group was in the low category. Cramond et al. (2005) found a very small correlation between verbal and figural creativity, whereas Wechsler (2006) states that verbal and figural creativity is significantly related. In creativity research that has been done, the correlation of verbal and figural creativity is highly dependent on the model of treatment accorded treatment as well as the type of instrument used for the measurement of any kind of creativity.

### Hypothesis Testing Results

Prior to hypothesis testing, normality and homogeneity tests have been tested on creativity data of prospective physics teachers. Normality test results on creativity data that has been done shows that some data is normally distributed and some are not normally distributed. This then implies the type of hypothesis test used. Hypothesis test was performed by non-parametric statistic technique using Mann-Whitney test. Test conducted on creativity physics test data that includes the initial test, the final test, N-gain verbal, figural and N-gain total. Table 1 shows the hypothetical test results of creativity data.

**Table 1.** Hypothesis Test Results of Creativity Data

Mann-Whitney	Sig.	Interpretation
Total Scores of Initial Test	.579	There was no initial creativity difference between the two sample groups
Total Scores of Final Test	.000	There is a final creativity difference between the two sample groups
N-gain of verbal creativity	.001	There is a difference in N-gain of verbal creativity between the two sample groups
N-gain of figural creativity	.018	There is a difference in N-gain of figural creativity between the two sample groups
N-gain total	.000	There is a difference of N-gain creativity between the two sample groups

From Table 1 data it can be seen that before the treatment the level of creativity of prospective teachers in the two groups is no different. This is reinforced by homogeneity test results that have been done previously indicating that the variance between the two groups is homogeneous. After treatment there was a significant increase in the experimental group. There is a difference of creativity increase, both verbal and figural creativity improvement in both groups significantly. From the results of statistical tests on this indicator obtained the conclusion of a significant difference in the increase of verbal and figural creativity between the two sample groups. Improvement in experiment group is higher than control group.

This significant difference is due to the learning by the laboratory that is carried out supporting the development of the creativity of prospective physics teachers. Among the favorable situations include: learning with a virtual laboratory brings openness, encourages questions, encourages generating something, responsibility and independence, emphasizes initiatives to classify data, estimate and test the estimates themselves, and communicate them to others.

The habituation of creative activities through virtual experiments as well as creative evaluations impacts the results of creativity measurements. This is relevant to the results of O'Reilly et al. (2001) which shows the comparison of two groups of creativity measurements

from creative arts programs and literary programs. In the measurements on various indicators of creativity can be seen creativity of participants from creative arts groups higher than the literary group on all indicators tested. Cropley & Cropley (2010) in his research shows that creativity is oriented to reality that involves knowledge and skills that can be trained. Williams (2002) views the issue of creativity assessment from a different perspective. In his research did not assess the product of creativity, but assessed the extent to which the task given was able to bring creativity in the first step.

Virtual lab-assisted learning is not only makes learning creative physics but is also used to train and equip the creativity of physics-minded teachers. According to Cremin (2006, 2009), the distinction between creative teaching and teaching for creativity tends to highlight the orientation of educators and the orientation of learners. Creative teaching involves educators in making learning more engaging and effective using imaginative approaches in the classroom. Teaching for creativity involves educators in identifying creative forces and encouraging learners' creativity.

Rawat et al. (2012) stated that a creative person is essentially a person who is able to form publicly accepted judgments in an unprecedented situation. A creative person achieves this goal through the ability to analyze the situation appropriately. Appropriate analysis causes him to be involved in the situation, and leads him to separate important and relevant facts capable of influencing the situation. A creative person, on the basis of this analysis can form an appropriate assessment of the situation and can create new solutions in an unprecedented or usual situation.

In their study Gunawan et al. (2013) have found that students who study with virtual labs have generic science skills higher than those conventionally studied. Learning with virtual labs improves the ability of logic inference and the ability to build physics concepts. The results of Siswanto et al. (2016) also found that physics learning using e-Lab is effective to improve students' generic science skills. Generic science skills have a positive effect on students' conceptual understanding on photoelectric effect, Compton Effect, and electron diffraction. Haseman & Jaaniste (2008) summarizes the relationship between creativity and its benefits to the general public: creating the right atmosphere, building the skills needed in the future workforce, generating new knowledge, and en-

couraging entrepreneurial activity.

## CONCLUSION

Based on the results of research and discussion that has been submitted, it can be concluded that the virtual lab model on electrical materials that have been developed give a significant influence on the improvement of creativity of physics teacher candidates. Creativity in the experimental group experienced a higher increase than the control group. Increased verbal creativity is higher than figural creativity in both groups. There are significant differences in creativity improvement in both groups, both in general and from verbal and figural aspects. This shows that learning with virtual labs that have been done proven to increase the creativity of prospective physics teachers.

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## THE EFFECT OF ELECTRO MAGNETIC FIELD INTENSITY TO BIODIESEL CHARACTERISTICS

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### ABSTRACT

Various studies of diesel fuel optimization have been done, one of them by using a permanent magnet on the fuel line, the lack of magnetic field intensity decreases along with time increasing by using an electromagnetic field. The purpose of this study is to analyse the biodiesel fuel characteristics due to exposure of electromagnetic fields in terms of the viscosity and vibration of these fuel molecules. Electromagnetic field is generated from wire coil of 5000-9000 on galvanum pipe with diameter of 1.5 cm and length of 10 cm and connected to 12 V batteries. Here, biodiesel fuel is inserted in a galvanum tube, magnetized for 1200 s, and tested its viscosity of the falling ball system by viscometer. Fuel functional groups as well as vibrations between fuel molecules are tested with FTIR. The results show that the magnetized fuel changes. The viscosity of fuels from 2933 to 2478 and an increasing in the absorption of fuel molecules ranges from 13-58%. Therefore, the increasing of vibrating fuel molecules decreases its molecular attraction tug. These indicate that the magnetized fuel molecule causes a changing in the fuel molecule, cluster becomes de-clustered. It is a potential method to clarify the phenomenon of fuel magnetization due to its efficient combustion process.

### ABSTRAK

Berbagai penelitian tentang pengoptimalisasian bahan bakar motor diesel telah banyak dilakukan, salah satunya dengan menggunakan magnet permanen yang dipasang pada saluran bahan bakar, kekurangannya adalah intensitas medan magnetnya berkurang seiring dengan bertambahnya waktu. Untuk mengatasi hal tersebut digunakan medan elektromagnet. Tujuan penelitian ini adalah menganalisis karakteristik bahan bakar biosolar akibat paparan medan elektromagnet ditinjau dari viskositas dan vibrasi molekul bahan bakar tersebut. Medan elektromagnet dihasilkan dari lilitan kawat sebanyak 5000-9000 pada pipa galvanum yang berdiameter 1.5 cm dan panjang 10 cm serta dihubungkan ke baterai sebesar 12 Volt. Selanjutnya bahan bakar biosolar dimasukkan dalam tabung galvanum untuk dimagnetisasi selama 1200 detik dan diuji viskositasnya dengan viscometer sistem bola jatuh. Gugus fungsi bahan bakar serta vibrasi antar molekul bahan bakar diuji dengan FTIR. Hasil penelitian menunjukkan bahwa bahan bakar yang dimagnetisasi memberikan perubahan karakteristik biosolar. viskositas bahan bakar menurun dari 2.933 menjadi 2.478 dan peningkatan intensitas absorpsi molekul bahan bakar berkisar 13-58%. Ini berarti, dengan bertambahnya molekul bahan bakar yang bervibrasi menyebabkan makin meningkatnya molekul bahan bakar yang memiliki gaya tarik antar molekulnya rendah. Dua hal ini menunjukkan bahwa molekul bahan bakar yang dimagnetisasi menyebabkan perubahan molekul bahan bakar yang awalnya menggumpal (*cluster*) menjadi tidak menggumpal (*de cluster*). Informasi ini berguna untuk penelitian lebih lanjut agar secara jelas dapat mengklarifikasi fenomena magnetisasi bahan bakar terhadap proses pembakaran yang efisien.

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**Keywords:** Biodiesel; Electromagnet; The magnetization fuel; Viscosity; The functional group

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## INTRODUCTION

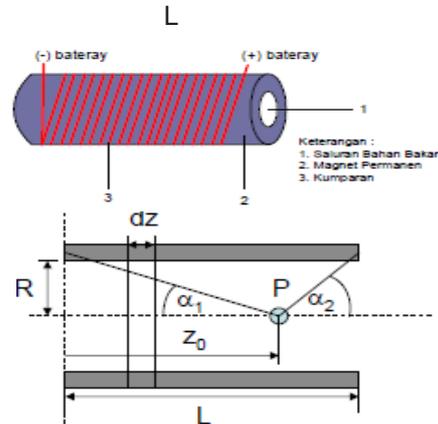
Nowdays, energy becomes an absolute necessity. Almost all of the facilities and infrastructure supporting human life is driven by energy. The used energy sources, oil sources, can not be renewed so that the supply is getting thinner. Usually, we just look for some way to save and reduce in consuming the fuel, also improve the fuel quality and find some renewable energy sources. Several studies have been done in order to save energy through improved combustion efficiency, e.g. adding certain additives into fuel which results in the *octane* value and *cetana* rising, better combustion process, and higher engine power (Fayyazbakhsh & Pirozfar, 2015; Samoilov et al., 2016).

Another way to improve the combustion efficiency is fuel magnetization. This process is done by putting a permanent magnet on the fuel line of the combustion chamber. Some researchers have reported that the magnetization of fuel resulting in a reduction of fuel consumption (9-30%) and the reduction of exhaust emission levels of HC (5-32%) and decreasing in CO (5-34.3%) (Faris et al., 2012; Kumar et al., 2014; Ugare, Dhoble, Lutade & Mudafale, 2014). However, both of them have the disadvantage that almost all the chemical additives that are widely circulated and used by the community contain metals that harm to human health. On the other hand, the use of permanent magnets, its power will be reduced over time.

One way to reduce the negative effects of those problems by making an instrument that is capable of functioning as a substitute for fuel chemical additives and permanent magnets. The nature of this instrument is non-chemical and uses the physical energy of a magnet generated by an electric current (electromagnetic field). This instrument when installed on petrol and diesel engines can minimize fuel consumption of up to 12.8-30% and lower levels of HC exhaust emissions by 44-58% and CO decreased by 35-80% (Okoronkwo et al., 2010; Fatih & Gad, 2010; Patel et al, 2014; Chaware, 2015). The electromagnetic field generated by this instrument reacts by weakening the hydrocarbon molecular bond structure inside the fuel, so that both hydrogen and carbon in the fuel can react better with oxygen to produce better combustion processes inside the combustion chamber (Guo, Liu, Chen and Yao t, 2011; Atar, Tipole, Bhojwani & Deshmukh, 2013)

Instruments is able to generate an electromagnetic field can be seen in Figure 1.

The instrument consists of a cylinder made of pipe galvanum of radius  $R$  and length  $L$ , tied by copper wire  $N$  windings and given electric current  $i$ . On this condition will be obtained electromagnetic field at  $P$ .



**Figure 1.** Electromagnetic field instrument (Bachtiar, 2007)

Dividing the length of the cylinder into a long- $dz$  elements, where in each  $dz$  containing

$$N \frac{dz}{L} \text{ coil} \quad (\text{Halliday \& Resnic, 2000}). \quad (1)$$

$$B_z(z_0) = \frac{\mu_0 N R}{2L} \int_0^L \frac{dz}{[(z_0 - z)^2 + R^2]^{3/2}}$$

$$R = z_0 \tan \alpha_1$$

$$R = (L - z_0) \tan \alpha_2$$

$$z - z_0 = R \cot \alpha$$

$$dz = \frac{R}{\sin^2 \alpha} d\alpha$$

$$[(z_0 - z)^2 + R^2]^{3/2} = \left( \frac{R}{\sin \alpha} \right)^3$$

Then the magnetic induction at point  $P$

$$B_z(z_0) = -\frac{\mu_0 N R^2}{2L} \int_{\pi - \alpha_1}^{\alpha_2} \frac{(R/\sin^2 \alpha)}{(R/\sin^2 \alpha)^3} d\alpha \quad (2)$$

$$= \frac{\mu_0 N}{2L} \int_{\alpha_2}^{\pi - \alpha_1} \sin \alpha d\alpha$$

$$= \frac{\mu_0 N}{2L} [-\cos(\pi - \alpha_1) + \cos \alpha_2]$$

$$B_z(z_0) = \frac{\mu_o N}{L} \left[ \frac{\cos \alpha_1 + \cos \alpha_2}{2} \right] \quad (3)$$

If the length of the solenoid bigger than its radius and  $z_0$  not close to zero or L, then the angle of  $\alpha_1$  and  $\alpha_2$  is small and it can be approximated by:

$$\alpha_1 = \frac{R}{z_0}; \alpha_2 = \frac{R}{L - z_0}$$

So that

$$B(z_0) = \frac{\mu_o N}{L} \left[ 1 - \frac{R^2}{4z_0^2} - \frac{R^2}{4(L - z_0)^2} \right] \quad (4)$$

If the solenoid radius is small, then the magnetic field becomes:

$$B = \frac{\mu_o \mu N i}{L} \quad (5)$$

Permeability  $\mu$  of any other material expressed as multiples  $\mu_o$  multiplier is called *the relative permeability*  $\mu_r$ , so that

$$B = \frac{\mu_o \mu N i}{L} \quad (6)$$

$$B = \frac{\mu_r N i}{L} \quad (7)$$

Notes :

- B: Magnetic field (Tesla)
- $\mu$ : permeability core material (core) = 31, 76
- $\mu_o$ : permeability of air vacuum = 1, 256 G cm / A
- N: number of inductor coils
- A: cross sectional area of the inductor (m<sup>2</sup>)
- L: length of the inductor (m)

In this research, fuel used is biodiesel derived from Pertamina. Biodiesel fuel is mixed fuel for diesel engines consisting of non-fossil biological oil by 10% which has been formed into *fatty acid methyl ester (FAME)* and 90% pure diesel subsidy. This fuel will gradually reduce role of solar. Non-fossil bio-oil added in diesel is known as biodiesel. The addition of biodiesel to diesel fuel is done because biodiesel has several advantages. According to Canakci and Van Gerpen (2001), the advantages of biodiesel include higher cetane number than diesel fuel, contains no aromatic

compounds, barely contains sulfur, and has a 10-11% oxygen content. In addition, emissions of carbon monoxide (CO), hydrocarbons (HC), and compounds of particulate matter (PM) in the exhaust gas generated less than that of petroleum diesel. Chemical structures of biodiesel fuel is shown in Figure 2.

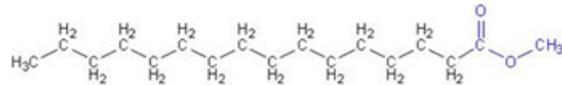


Figure 2. Chemical structure of biodiesel.

The atomic theory illustrates the phenomenon that the negative electrons that rotate around the atom's nucleus influence whether or not a substance can be influenced by a magnetic field. As the elements contained in the hydrocarbon fuel which comprises (H<sup>+</sup>) and (C<sup>-</sup>) where the number of electrons is not the same, then the substance can be influenced magnetic field.

In physics, the cause of magnetism in the object is atomic magnetic moments associated with the electron movement, the electron moves in its orbit around the nucleus and the electron spins on its axis (spin), so it has a spin angular momentum, i.e. the spin up (+1/2) and spin down (-1/2) as presented in Figure 3. Thus, fuel is a substance that can be affected by a magnetic field.

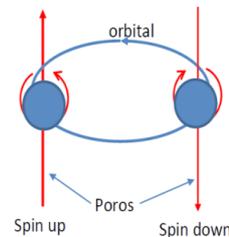


Figure 3. The magnetic moment associated with orbital and spin of electrons.

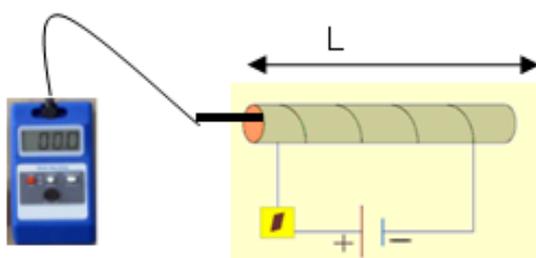
Based on the theory of the bonding moment when a polar bond such as OH is left in a magnetic field, the bond will experience a number of back forces. This force simply pushes the magnetic field to free the bond in the field. The more polar bonds experience a greater force than the less polar ones. HC including non-polar bond that is forming a major element in the fuel, because the value of the bond moment simply by 0.4 D (*Debye*). However a strong magnetic field can interfere with and affect the HC bond. Although the bonds between HC atoms are not released from each other, but at least the bond strength will weaken slightly.

Provision of an electromagnetic field in the fuel molecules also cause adverse reactions between molecules (*de-clustering*) to form the optimal distance between the molecules of fuel. Molecular activity increased as a result of this magnetic field will also cause a molecular collection was split so that it becomes smaller molecules and cause fuel viscosity decreases (Rosensweig, 1989; Marques *et al* 1997).

The purpose of this study was to analyze the characteristics of biodiesel fuel as a result of exposure to electromagnetic fields in terms of viscosity and molecular vibration of the fuel.

## METHOD

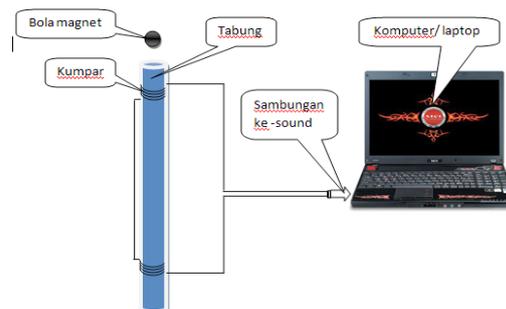
Electromagnetic fields generated by wrapping the wire diameter 0,2 0 mm on the tube galvanum with the number of windings 5000, 7000 and 9000, then given a DC voltage of 12 volts.



**Figure 4.** A series of strong electromagnetic fields gauges.

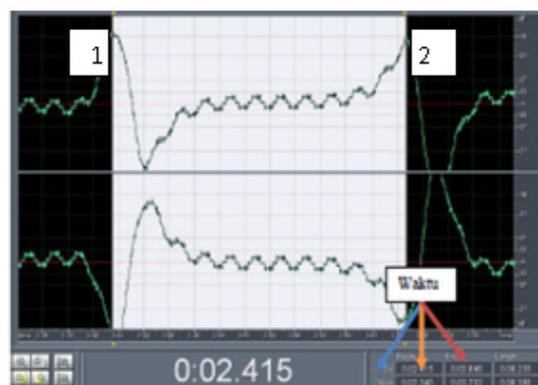
The next step is to measure the magnitude of the electromagnetic field strength by using Digital Teslameter Figure 4. These results were compared using Biot Savart formula as in equation 6.

Biodiesel fuel is exposed to electromagnetic fields which have a strong magnetic field intensity of 900-1500 Gauss (5000-9000 loops) during 0-1200 s. This is done by inserting the fuel in a galvanized tube that has been tied copper wire. The viscosity test was performed using a modification of the falling ball measurement system. This device consists of a sensor coil which is connected with computers and *adobe audition* 1.5 program as a translator signal from the sensor coil. The advantage of this method is its accuracy to detect until 1/1000 in a second. The series of gauges viscosity is shown in Figure 5.



**Figure 5.** Series of Viscosity Gauges (Salim, 2012)

How the viscosity test kit works: the magnetic ball is dropped into the tube. When the magnetic ball moves through the coil at points A and B there will be a current on the wire. The current will be read by the existing sound card on the computer in waveform with decibels (dB) on y axis and time (seconds) on the x axis. When the magnet ball passes through the first coil and the second coil, then for the reading the time is taken as the ball passes through the initial and final coils. This data is recorded by software as in Figure 6.)



**Figure 6.** Biodiesel viscosity test results recorded on a computer.

At the beginning peak of wave 1 and wave 2. Time window shows the time data in numerical format. This data is presented in standard time display format (Minutes: second: per-thousand-second). The amount of viscosity can be calculated by the following equation.

$$\eta = \frac{2r^2 g (\rho_b - \rho_f)}{9L} \quad (7)$$

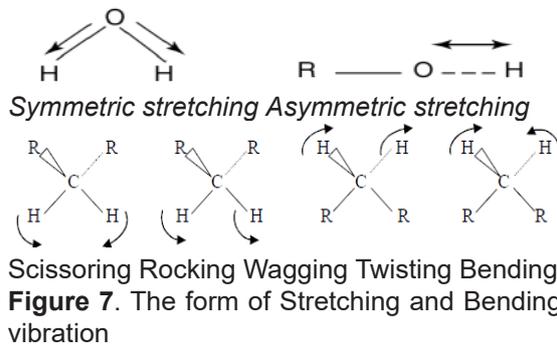
Notes:

- $\eta$  : fuel viscosity (cSt)
- $r$  : radius of the sphere (0.00215 m)
- $t$  : travel time ball in a fluid (s)

g : gravity (9.8 m/s<sup>2</sup>)  
 L : length of trajectory in the travel  
 $\rho_b$  : Desitas ball (27638.475 kg/m<sup>3</sup>)  
 $\rho_f$  : Density of fuel (879 kg/m<sup>3</sup>)

Viscosity test has been done repeatedly, each five times for one sample. It has been done for biodiesel before passing through the magnetic field and after passing through a magnetic field.

Molecule vibration measured using FTIR *spectroscopy IR Prestige-21 Shimadzu Co. Ltd.* The working principle of this tool is based on the number of *infrared* rays frequency are absorbed by certain energy level passes a compound under investigation, then the energy of these frequencies will be transferred to the compound that causes amplitude changes molecular vibration. There are two kinds of vibration, namely stretching vibration and bending (Figure 7), stretching vibration is a rhythmic movement along the axis of the bond so that the distance between atoms is increased or decreased. Bending vibration occurs because of the change of bond angles between the bonds on an atom.



*Infrared* absorption information generally provided in the form of the spectrum with a wave length or wave number (cm<sup>-1</sup>) as the abscissa x and the intensity transmittance or percent absorption as ordinate y. This FTIR test serves to identify the functional groups contained in the biodiesel fuel either before or

after passing through an electromagnetic field. To change the % transmittance to absorbance using *Lambert-Beer* formula:

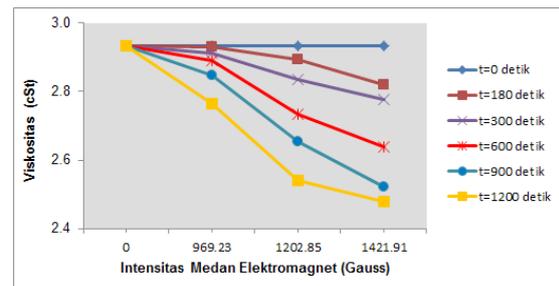
$$A = -\log T \tag{7}$$

Notes:  
 A = Absorption  
 T = Transmission

## RESULTS AND DISCUSSION

Table 1 shows the average of measurement electromagnetic fields as much as five times by using a digital Teslameter as shown in Figure 4 and using the formula t Bio Savart (Equation 6). It appears that the greater its windings the greater the strength of electromagnetic field generated. However, if the windings is too much causes the obstacles becomes large, and small current, so electromagnetic field is small, thus there is a limit to the maximum threshold for the number of windings.

Figure 8 shows a graph of the viscosity with the intensity of the magnetic field, it appears that the higher the magnetic field strength given to biodiesel would result in increasingly lower viscosity values or in other words the magnetic field strength is inversely proportional to viscosity hydrocarbons. On the other hand, exposure to a magnetic field on the fuel also affects the viscosity value, the longer the exposure time of the magnetic field the smaller its viscosity. This shows the effect of *de clustering* tendency in the hydrocarbon molecules that occur due to magnetization.



**Figure 8.** Graph of relation between Intensity of electromagnetic field and viscosity.

**Table 1.** Data of electromagnetic field measurements

$\Phi$ coil (mm)	Number of turns	V (volt)	i (mA)	R (M $\Omega$ )	BT (Gauss)	BP (Gauss)
0, 2	5000	12	48, 4	251, 7	969, 23	969, 13
0, 2	7000	12	42, 9	283, 3	1202, 85	1201, 39
0, 2	9000	12	39, 5	288, 1	1421, 91	1419, 57

Notes: BT : Electromagnetic field calculated by theory (Bio Savart's formula); BP : electromagnetic field calculated by practice (Teslameter)

Smallest biodiesel viscosity occurs in the magnetic field exposure times for 1200 s. This exposure time is used to detect biosolar vibrations with FTIR.

Figure 9 is a graph of test results for biodiesel FTIR either magnetized or not. The greater the electromagnetic field strength given, the smaller the percentage of transmittance or the greater the percentage of absorbs according to the Lambert-Beer formula, but no changes in the structure of the magnetized biosolar compound. In addition, the results of these tests inform the functional groups contained in the biodiesel, *i.e.* the carbon-hydrogen bond (CH *stretching*), a carbon-oxygen bond (C = O *stretching*), carbon-carbon bond (CC *stretching*) and carbon-oxygen bond (CO *stretching*), the results are consistent with the molecular structure of the biodiesel that has been investigated by Berman et al., 2016.

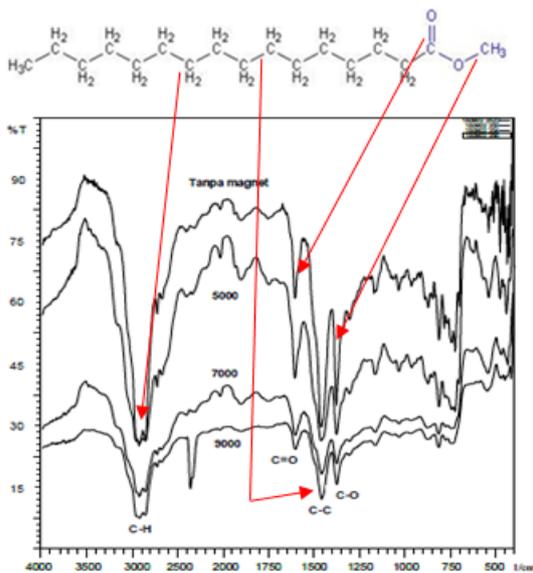


Figure 9. The FTIR spectrum of biodiesel.

With the help of Figures 9 and Lambert Beer formula at equation 7 obtained data such as the Table 2 indicating that the molecule of biodiesel that does not pass through the magnetic field transmittance percentage relatively

Table 2. Percentage of Biodiesel Absorption Intensity

Group	Wave numbers (cm <sup>-1</sup> )	Percentage of absorption			
		No magnets	969.23 Gauss	1202.85 Gauss	1421.91 Gauss
CH	2850-2991	68, 74	80, 05	84, 25	91, 61
C = O	1690-1900	31, 59	42, 47	44, 99	45, 12
CC	1500-1600	56, 54	63, 92	81, 22	82, 36
CO	1080-1350	47, 93	58, 27	72, 33	7 5 85

larger or the absorption is smaller compared with the fuel molecules pass through a magnetic field.

C-H bonds have the greatest absorption intensity followed by a C-C bond, CO and the smallest C=O bond as presented in Figure 10.

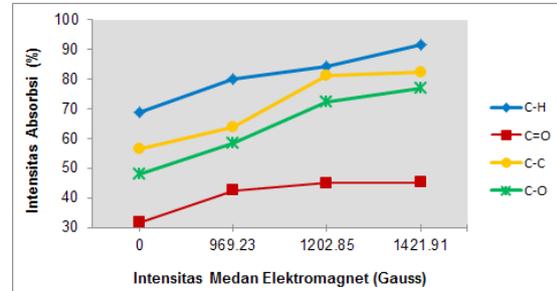


Figure 10. Chart of relationship between electromagnetic field intensity and intensity of absorption

The intensity of absorption can be correlated with the vibration of the functional group. Vibration occurs because the fuel molecule that gains additional energy (magnetic energy) causes the atom to be excited to a higher energy level, the excitation of this atom does not lead to the release of the molecular bond of fuel but merely vibrate. Equation (8) which is famous for Arrhenius equation can be illustrated to explain the phenomenon, on the condition of constant temperature and magnetic energy increases (the energy gap decreases) then the value of N (the number of molecules vibrating) increases. This condition is consistent for all fuels functional groups shown in Figure 10.

$$N = N_0 \cdot \exp\left(\frac{-E}{kT}\right) \tag{8}$$

Notes:

- N : number of molecules after process
- N<sub>0</sub> : number of molecules before the process
- E : energy
- k : Boltzman constant
- T : temperature

Table 3 shows changes in the value of

**Table 3.** Percentage increase of the number of vibrations of biosolar molecules passing through the magnetic field

Group	Wave numbers (cm <sup>-1</sup> )	Percentage of additions number of vibrations		
		969.13 Gauss	1202.85 Gauss	1421.91 Gauss
CH	2850-2991	16,453	22,563	33,270
C = O	1690-1900	34,441	42,418	42,830
CC	1500-1600	13,053	43,651	45,667
CO	1080-1350	21,573	50,908	58,252

the molecular vibration which are magnetized compared with the fuel molecules are not magnetized. It appears that the greater the electromagnetic fields given to biodiesel then the greater the number of molecules vibrate. The increasing of fuel molecules vibrate led to an increase of fuel molecules that have a low-molecular attractive force means that the lower the energy required for breaking bonds between atoms. It is related to the viscosity and surface tension of fuel decreases. Thus, it can be concluded that the tensile force of the hydrocarbon molecule decreases after it is affected by the magnetic field.

### CONCLUSION

Based on this study, it can be concluded that the effect of electromagnetic fields on biosolar characteristics: 1) Electromagnet field on the fuel molecules does not change the molecular structure of biodiesel, but it affects to the absorption intensity, where the higher electromagnetic field strength are given to molecule, the greater amount of fuel molecules to vibrate or more molecules that have the attractive force between fuel molecules is low; 2) Higher strength of the electromagnetic field given to the biosolar molecule, lower viscosity of biodiesel; 3) Both of them amplify the phenomenon where the magnetization of the biodiesel is a product of *de-clustering* effect, this information is useful for further research in order to clearly be able to clarify the phenomenon of magnetization of the fuel-efficient combustion process.

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# THE EFFECT OF INQUIRY BASED LEARNING ON THE PROCEDURAL KNOWLEDGE DIMENSION ABOUT ELECTRIC AND MAGNET CONCEPT

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## ABSTRACT

The purpose of this study to determine the effect of the use of inquiry-based learning to the increased dimensions of procedural knowledge in electrical magnetic material. The study used a quasi-experimental research methods with research design is non-equivalent control group design and a sampel are selected with the random sampling method. The experimental group was taught by the method of inquiry-based learning and the control group was taught by conventional methods. Collecting data using the instrument of multiple-choice test that developed through this research with category of validity is valid, reliability with category of reliable, index of discrimination with category of low, and level of difficulty with category of medium. The results of the data analysis by using the formula *N-Gain* and *t-test* showed that an increase in the dimensions of procedural knowledge significantly for experimental class and less significant for control class. Based on the results of this study suggested to the teacher to always use the method of inquiry learning that an increase in procedural knowledge dimension, especially for topics related to experimental physics.

## ABSTRAK

Tujuan penelitian ini untuk mengetahui pengaruh penerapan pembelajaran berbasis inkuiri terhadap peningkatan dimensi pengetahuan prosedural pada materi listrik magnet. Penelitian menggunakan metode penelitian eksperimen semu dengan desain penelitian *non-equivalent control group design* dan sampel dipilih dengan menggunakan metode random sampling. Kelompok eksperimen diajarkan dengan metode pembelajaran berbasis inkuiri dan kelompok kontrol diajarkan dengan metode ceramah. Pengumpulan data menggunakan instrumen tes pilihan ganda sebanyak yang dikembangkan melalui penelitian ini dengan validitas termasuk kategori valid, reliabilitas baik, indek daya pembeda dengan kategori kurang, dan tingkat kesukaran dengan kategori sedang. Hasil analisis data dengan menggunakan rumus *N-Gain* dan *uji-t* menunjukkan bahwa terjadi peningkatan dimensi pengetahuan prosedural secara signifikan pada kelas eksperimen dan kurang signifikan untuk kelas kontrol. Berdasarkan hasil kajian ini disarankan kepada pengajar (Guru) untuk selalu menggunakan metode pembelajaran inkuiri agar terjadi peningkatan dimensi pengetahuan prosedural, terutama untuk topik-topik fisika yang terkait dengan percobaan.

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**Keywords:** Dimesion of procedural; Experimental physics; Inquiry method

## INTRODUCTION

Indonesia's participation in several events of the Trends in International Mathematics and Science Survey (TIMSS) has not shown satisfactory results. Indonesia ranked

32 out of 38 countries at the beginning of the year of its participation in TIMSS. Furthermore, Indonesia was ranked 36 out of 45 countries in 2003, ranked 35th out of 48 countries in 2007 and ranked 40th of 42 countries in 2011 (TIMSS, 2011). This low ranking includes cognitive, affective and skill domains.

The cognitive domains based on the

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framework of Anderson and Krathwohl (2001) include the dimensions of knowledge, namely; dimensions; (1) factual; (2) conceptual; (3) procedural; and (4) metacognitive. The dimensions of factual include knowledge of (i) terminology, and (ii) details and elements. The dimensions of conceptual include knowledge of (i) classification and categories, (ii) principles and generalizations, and (iii) theories, models, and structures. While the dimensions of procedural include knowledge of (i) specific skills and algorithms, (ii) techniques and methods, and (iii) criteria for the use of a procedure. Finally, the dimensions of metacognitive are knowledge of (i) strategy, (ii) cognitive operations, and (iii) about themselves.

According to Anderson and Krathwohl (2001) it can be summarized that the dimensions of procedural are more emphasized on the process, 'how' something can happen and how it can be solved by using certain steps in the solution. Several other experts further argue that the dimensions of procedural can be defined as a process of science activity that requires methods, steps to solve a rise problem to obtain meaningful conclusions at the experimental effort stage. This is in accordance with Hemado's (2013) opinion, which stated that, "Procedural knowledge is the acquisition of skills related to step-by-step actions in solving problem context". In line with the opinion expressed by Lanzer and Taatgen (2013) that "Procedural knowledge is critical to instruct action, yet being mostly tacit it is difficult to access".

Based on this definition, it appears that the dimensions of procedural knowledge are contained in the syntax of inquiry-based learning. These dimensions of procedural knowledge in terms of problem identification skills, formulating research questions, designing investigations, and communicating results are reflected in inquiry-based learning (Krugly & Taylor, 2004; Selby, 2006). The advantages of inquiry study have been studied by some researchers and it gives a significant outcome to student achievement. Among them are mastery of concepts, critical thinking skills and scientific literacy can be improved through the implementation of inquiry-based learning (Kurniawanti, Wartono, & Diantoro, 2014; Arief & Utari, 2015). Furthermore, the National Science Teachers Association (NTSA) concluded that learning by inquiry approach is capable of encouraging students to conduct investigation and gain knowledge (NTSA, 2004).

Some research results also show that inquiry-based learning can increase students' metacognitive (Kipnis & Hofstein, 2008), build student knowledge, reasoning and arguments (Wilson, CD, Taylor, JA, Kowalski, SM, & Carson, J., 2010; Nivalainen, Asikainen, & Hirvonen, 2013), enhancing conceptual understanding (Sarwi, Sutardi, & Prayitno, 2016), and the dimensions of procedural and conceptual knowledge can last longer if taught by inquiry approach (Kwon, Rasmussen & allen 2005). Moreover, inquiry-based teaching also has a strong analogy with Problem solving and Problem Based Learning approaches (Parr & Edwards, 2004).

Based on the opinion of the experts and their research results, then course-based learning inquiry can be extended its use to improve the procedural knowledge on the concept of physics, such as magnetic electricity. The structure of the magnetic case resolution is closely related to the dimensions of procedural knowledge (McCormick, 1997). Therefore, the purpose of the study was to determine the effect of the application of inquiry-based learning to the increasing dimensions of procedural knowledge on magnetic electrical materials.

In particular it is important to explore improvement of the procedural knowledge dimensions as well as exploring empirical information on indicators of achievement from the dimensions of procedural knowledge as the impact of inquiry-based learning. Improvement of the procedural knowledge is intended to the components of skills, rules, actions, and outcomes. The enhancement of the components of procedural knowledge can be determined after being compared between the treated group (experimental class) and the untreated group (control class). The comparisons between the two groups can be made or justified statistically if both groups have normally distributed and homogeneous data (Arikunto, 2009).

## METHOD

The method and type of research used are quantitative and quasi experimental with non-equivalent Control Group Design research as shown in Table 1.

The research is done through two stages, namely the first stage of instrument development and the second stage is the implementation of research or implementation of research instruments that have been developed in the first stage. The development of research instru-

ments begins with the definition of terms from theoretical and operational dimensions of procedural knowledge, the preparation of indicators, the writing of test items, the process of limited trials, testing the validity and reliability of the instruments.

**Table 1.** Research Design

Classes	Sampling	Pre test	Treatment	Post test
Exp	Non-random	Q1	Inquiry	Q3
Control	Non-random	Q2	Discourse	Q4

(Fraenkel, Wallen & Hyun. 2012)

Implementation phase of the instrument is done by using quasi experimental research method begins with sample selection, preparation of inquiry-based learning design for experimental class (28 students) and discourse-based learning design in control class (27 students). Implementation of research on experimental class is done by using syntax include; (i) formulating the problem, (ii) preparing the hypothesis, (iii) designing the experiment, (iv) conducting the experiment, (v) collecting and analyzing the data, and (vi) drawing conclusions. In the control group implementation of learning in accordance with the syntax of learning discourse method.

To measure the improvement of the procedural knowledge dimensions, an instrument called the Measurement Instrument for the Dimensions of Procedural Knowledge (MI-DPK) on magnetic electrical materials was developed. The MI-DPK test instrument consists of 20 multiple-choice items on magnetic material. Instrument validity test using product moment Pearson correlation equation and reliability test using Cronbach's Alpha (CA) equation (Arikunto 2009).

The limited test results of the instrument show that the average validity is 0.44 (valid), reliability is 0.76 (good), the difficulty level is 0.30 (medium), and the difference is 0.18 (low). After the validity test by the experts and limited trials, 13 valid items were obtained and used to measure the dimensions of students' procedural knowledge on magnetic electrical topics.

Data were collected using MI-DPK tests prior to treatment (pretest) and after treatment (posttest), both for the control group and experimental group. In order to be able to recognize the increase in procedural knowledge, the MI-

DPK test is based on three procedural knowledge indicators (Cauley, 1986), ie skills, rules, actions and goals of subject learning. Based on these indicators are compiled test items on magnetic electrical material with a composition of five items of the skills indicator, four items from the rules indicator, six items from the action indicator, and five items from the goals indicator. Data analysis in this research use t-test statistic equation and normalized G-factor (N-Gain) calculation (Cheng, 2004).

## RESULTS AND DISCUSSION

Data obtained in this research is quantitative data which is derived from the test results using MI-DPK. Data on pre-test results in the control class (27 students) and in the experimental class (28 students) were used to test normality and homogeneity.

The result of normality test of data using Liliefors Test showed that the control class data and experiment class were normally distributed with  $L_{calc}$  of 0.131 and 0.156 respectively. The data  $L_{table}$  is 0.163, it can be concluded that either the data from the control group or from the experimental group is normally distributed. Homogeneity test was done by using variance analysis and obtained for control group 139.96 and experimental group 220.97. Based on the two values of the variance, the value of  $F_{calc} = 1.58$ , while the value of  $F_{table} = 1.98$  and this shows that the pre-test results are homogeneous. To know whether the increase is at a significant level of 0.95 or not, it is necessary to test the hypothesis.

The null hypothesis formulated is that there is an influence of the use of inquiry methods to the increasing dimensions of procedural knowledge of high school students in dynamic electrical topics". Hypothesis testing is based on the result of different test analysis between experimental class taught by inquiry method and control class which is taught by discourse method by using t-test formula. A summary of the results of the hypothesis test and decision test is shown in Table 2.

The impact of the implementation of inquiry methods in increasing dimensions of procedural knowledge can be obtained from the calculation of normalized N-Gain values. The N-Gain values for the experimental and control groups were 0.424 and 0.174, respectively. This means that the experimental group taught by inquiry method increases the dimension of procedural knowledge more significantly than

the control group which taught by the discourse method. To assess the impact of inquiry-based learning, it is necessary to examine the increasing dimensions of procedural knowledge for each component.

**Table 2.** Results of pretest and posttest data analysis

Class	Data of	Average	$t_{calc}$	$t_{table}$	Decision
Experiment	Pretest	33.19	10.74	2.01	$H_a$ accepted
	Posttest	68.17			
Control	Pretest	33.54	4.67	2.01	$H_a$ accepted
	Posttest	48.46			
Experiment	N-Gain	0.42	4.03	2.01	$H_a$ accepted
Control		0.17			

**Procedural Knowledge on Skills Component**

The procedural knowledge data per indicator for the experimental class is shown in Table 3 and for the control class shown in Table 4.

**Table 3.** Pretest and posttest procedural knowledge data of the experiment group

Indicators	Pretest	Posttest	N-Gain	Categories
Skills	1.6	2.5	0.38	moderate
Rules	1.0	3.3	2.19	high
Actions	1.2	2.7	0.52	moderate
Goals	1.2	2.9	0.93	high

**Table 4.** Pretest and posttest procedural knowledge data of the control group

Indicators	Pretest	Posttest	N-Gain	Categories
Skills	1.8	1.5	-0.14	low
Rules	1.3	2.0	1.00	high
Actions	1.4	1.9	0.19	low
Goals	0.9	2.6	0.81	high

The procedural knowledge indicator on the skill component is knowledge related to the selection of tools and materials needed to understand a concept. After applying inquiry learning on magnetic electrical topics, there was an increase in skill indicators by 0.38 with

moderate category for experimental class and 0.14 with low category for control class. Improvements that occur in the experimental class were occurring since they are supported by one of the inquiry-based learning syntax that trains students in choosing the experimental tool or material. This result is in accordance with the data obtained by previous research, where there is an increase in students' ability to do experiments after applied guided inquiry method (Kurniawati, Wartono, & Diantoro, 2014, Damawati & Juanda, 2016).

**Procedural Knowledge on Rules Component**

Indicators of procedural knowledge on the components of rules related to the understanding and the ability to know the procedure of problem resolution appropriately and correctly. According to Anderson and Krathwohl (2001) the dimension of knowledge is also related to knowledge of skills and algorithms. Therefore, in this research there are four multiple choice problems about electric circuit developed related with procedure to know the increasing of knowledge dimension in rules component.

The data for this indicator is shown in Table 3 for the experimental class and Table 4 for the control class. The results of data analysis shows that after the students are taught by method of inquiry there is an increase of component of rules of 2.19 with high category of experimental class and 1.00 with high category of control class. There is a relatively high increase, compared to other indicators, because the three syntax of inquiry-based learning fits perfectly with the procedural rules, namely (i) the formulation of the problem, (ii) the preparation of the hypothesis, and (iii) designing or assembling experiments (McCormick, 1997; Cauley, 1986; Anderson & Krathwohl, 2001).

Increasing the procedural knowledge dimension of the rules component is also in accordance with the results of research conducted by Sarwi, Sutardi, and Prayitno (2016), where the application of guided inquiry method can improve procedural understanding in conducting experiments. The relevant research results is also demonstrated by Darmawati and Juanda (2016), where inquiry-based learning can improve reasoning ability. The reasoning abilities are the main factors for procedural understanding (Cauley, 1986).

### **Procedural Knowledge on Action Component**

The action indicators on this knowledge dimension are related to the problem-solving ability appropriately and may indicate the relationships between methods and techniques (Cauley, 1986). Therefore, to measure the indicators, six multiple choices problems have been developed regarding the procedural actions in electrical circuitry. The data for the action indicator are shown in Table 3 of the experimental class and Table 4 for the control class. The results of data analysis showed that after applied inquiry based learning there was an increase of indicator score of 1.5 with moderate category for experimental class and 0.19 with low category for control class. An increase of 1.5 in the medium category, one reason is that there is only one stage of inquiry-based learning syntax which is related to procedural knowledge of action, collecting and analyzing data (Junike, Halim & Yusrizal, 2016).

Students' action in collecting and analyzing data needs to be supported by the ability to think hypothetically deductive, combinative and reflective thinking, as well as proportional thinking. The results of research by Derlina and Mihardi (2015) show that inquiry-based learning can improve the ability of reflective and reflective thinking in the medium category, while the ability to think proportionally in the high category.

### **Procedural Knowledge on Results Component**

The indicators results components are related to understanding the sequence of actions taken to achieve the objectives (Cauley, 1986; Anderson & Krathwohl, 2001). Therefore, in the research five questions of multiple choices on electrical topic have developed to measure indicator of results component. The data for the indicators are shown in Table 3 for the experimental class and Table 4 for the control class.

The result of data analysis shows that the implementation of inquiry learning model has increased this indicator by 0.93 with high category for experimental class and 0.81 for control class. Despite an increase in the high category, it remains lower than the increase in the rule component indicator (2.19). One reason is that the syntax of inquiry learning associated with this indicator is only one stage, that is, the activity of making conclusions. This means that the time spent by students to carry out

lesson-related learning activities with results indicators is quite short. Relevant research in accordance with the results of this study was conducted by Sarwi and Khanafiyah (2010), where the application of open inquiry methods can improve scientific work skills in the course of the wave. Scientific work skills are the main factors for understanding the sequence of actions in achieving the learning objectives.

## **CONCLUSION**

Based on the results of this study obtained the conclusion that the implementation of inquiry-based learning in general affects the increasing dimensions of procedural knowledge. Four indicators of procedural knowledge dimensions, the highest increase is the indicator of rules component in the experimental class as well as in the control class. The most low-level indicators are skills component in the experimental class as well as in the control class.

The results of this study also inform that the dimensions of procedural knowledge, as one dimension of knowledge in the cognitive domain of Taxonomy Bloom revised edition, can be improved through the implementation of inquiry-based learning, especially open and guided inquiry types. The indicator of the rules component that achieves the optimal increase occurs because of continuous inquiry-based learning process support and simultaneous tracing of this component. It means that there is a great opportunity to improve the output of other components by innovating on this inquiry model.

Based on the results obtained from this research it is propose to stakeholders or anyone who has the power to manage policies, to be encouraged to teachers and lecturers using inquiry methods to improve the dimensions of procedural knowledge. Using the same method may also be enhanced the dimensions of conceptual, factual and metacognitive knowledge. To prove this allegation, further research is needed.

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