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Jurnal Penelitian Fisika dan Aplikasinya (JPFA)

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Kementerian Riset, Teknologi, dan Pendidikan Tinggi

TERAKREDITASI PERINGKAT 2

Akreditasi berlaku selama 5 (lima) tahun, yaitu
Volume 6 Nomor 1 Tahun 2016 sampai Volume 10 Nomor 2 Tahun 2020

TERAKREDITASI

Jakarta, 9 Juli 2018
Direktur Jenderal Penguatan Riset dan Pengembangan

DIREKTORAT
JENDERAL
PENGUATAN RISET
DAN PENGEMBANGAN

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Ministry of Research, Technology, and Higher Education Republic of Indonesia
Number: 21/E/KPT/2018, Date: July 9, 2018
Regarding the Results of Scientific Journal Accreditation 1st Period in 2018

Title of the Scientific Journal
Jurnal Penelitian Fisika dan Aplikasinya (JPFA)
E-ISSN: 2477-1775

Publisher: **Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya**

Specified as the Scientific Journal

ACCREDITED

ACCREDITED GRADE 2

`QR Code`

Accreditation is valid for 5 (five) years, that is
Volume 6 Issue 1 Year 2016 until Volume 10 Issue 2 Year 2020

Jakarta, July 9, 2018
General Director of Strengthening Research and Development

Signed and seal

Dr. Muhammad Dimyati
NIP 195912171984021001

Translated by

Utama Alan Deta
Managing Editor of JPFA
JPFA-UNESA

CERTIFICATE

Directorate General of Research Reinforcement and Development
The Ministry of Research, Technology, and Higher Education

Name of the Scientific Journal

Jurnal Penelitian Fisika dan Aplikasinya (JPFA)
(Journal of Research in Physics and its Application)

E-ISSN: 2477-1775

Publisher: Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya

Conferred as Scientific Journal with

ACCREDITED WITH RANK 2

This accreditation is valid for 5 (five) years, namely
From Volume 6 Number 1 in 2016 until Volume 10 Number 2 in 2020

Certified as true and correct translation
Secretary of UPT PUSAT BAHASA UNESA

Syafi'ul Anam, Ph.D.
Official Reg. No. 197809162006041001

Jakarta, 9 July 2018
Director General of Research Reinforcement and Development

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Research Article

Problem-Based Learning Model for Three-Phase Induction Motor

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Abstract

This study aims to examine the Problem-Based Learning (PBL) model to improve the understanding of electromagnetic induction material in three-phase induction motor. Most of the students attending the Electrical Machine course have low understanding upon the working principles of the three-phase induction motor, in particular the basic theory of the relationship between the electromagnetic field and the three-phase induction motor. This study involved seventeen students of Electrical Engineering Education Study Program of Universitas PGRI Madiun in East Java. Data were collected through observation and tests, with the statistical test of research using paired sample t-test. This quasi-experimentresearch employed one-group pre-test and post-test design. The results showed that the application of PBL model with video simulation and practices improve students' understanding of the materials. The learning process by utilizing simulated animation video and the practices of unloading three-phase induction motors directly, the students' understanding of the working principles of three-phase induction motors increases with the average of N-Gain score. These results indicate the use of video and hands-on practice become effective way to deliver complex and abstract material to students. It is also believed that the learning on electromagnetic induction can be carried out more efficiently. Additionally, such learning model is believed to ease students understanding in physics.
Keywords: *problem-based learning, induction motor, three-phase, understanding, electromagnetic field*

Aplikasi Model Problem Based Learning Untuk Meningkatkan Pemahaman Tentang Induksi Elektromagnetik Pada Motor Induksi Tiga Fasa

Abstrak

Penelitian ini bertujuan untuk mengetahui permasalahan model problem learning untuk meningkatkan pemahaman materi induksi elektromagnetik pada motor induksi tiga fasa. Mayoritas siswa yang mengambil matakuliah mesin listrik belum memahami prinsip kerja motor induksi tiga fasa. Teori dasar hubungan antara medan elektromagnetik dan motor induksi tiga fase belum dikuasai oleh para siswa. Sampel terdiri dari 17 siswa di Prodi Teknik Elektro Universitas Pendidikan PGRI Madiun. Teknik pengumpulan data menggunakan oservasi dan tes. Metode penelitian menggunakan quasi experiment dengan desain One-Group Pretes Postes Design. Uji statistik penelitian menggunakan paired sample t test. Hasil penelitian menunjukkan bahwa penerapan model PBL dengan simulasi dan praktik video dapat meningkatkan pemahaman siswa terhadap materi yang diberikan. Melalui proses belajar dengan

memanfaatkan simulasi video animasi dan praktek pembongkaran motor induksi tiga fasa secara langsung, pemahaman siswa tentang prinsip kerja motor induksi tiga fasa dapat meningkat, dengan skor N-Gain. Hasil ini menunjukkan bahwa video media dan praktik langsung dapat menjadi cara yang efektif untuk memberikan materi yang cukup kompleks dan abstrak kepada mahasiswa. Dengan penerapan metode ini pembelajaran mengenai induksi elektromagnetik dapat dilaksanakan dengan lebih efisien. Dalam perkembangannya, model pembelajaran tersebut diharapkan dapat mempermudah siswa dalam memahami fisika.

Kata Kunci: *problem based learning, motor induksi, tiga fase, medan elektromagnetik*

I. INTRODUCTION

Electric motors are in separable part of our everyday life that we seldom give them a second thought [1]. One of the most familiar types of electric motors is the type of induction motor. Induction motors are employed in textile mills, agriculture, and almost all the manufacturing industries to drive the loads because of its rugged construction and ease operation [2]. The basic principle of the induction motor is the magnitude of the force varies directly with the strength of the magnetic field and the amount of current flowing in the conductor.

In general, the rotor of an electric motor lies within a magnetic field created by the stator. The magnetic field induces a current within the rotor, and the resultant force caused by the magnetic fields in the stator and rotor (and thus torque) causes it to turn [3].

Previous research about three-phase induction motor have been carried out by Zuriman. He made a simple method for operating the three-phase induction motor on single phase supply [4]. Besides that Kishor et al also explained about three-phase induction motor using written pole technology [5]. The modified stator winding also was researched by C. Saravanan et al, where they use Matlab Simulink to help for the simulation of modified stator winding [6]. Another research on learning models about the induction motors was also conducted by Ade Pajar, where he developed an asynchronous type induction motor for learning media, but without being equipped with animated videos.

Regarding these studies, this research discusses the electrical engineering learning for the students, such as combining the practices model with a three-phase induction motor medium. The learning process was also equipped with the animated video that explained the three-phase induction motor. So that students not only practice, but also make observations, analyze, and solve problems given.

Nevertheless, there are still many problems faced by students at the time of learning the topics related to electric motors. The students only know that when the current flows the electricity, the motor will work. Data obtained from the test taken by the sixth-semester students majoring on Electrical Engineering about the electric motor concept, all students assumed that the induction motor will work if it is electric current, so the students' understanding is that the electric

current is to drive the induction motor. At the moment the induction motor is dismantled, only 17.64 % students mention that the parts of the induction motor but cannot explain the relationship of each part with the working principles of the induction motor.

The results were obtained from the pre-test which included problems mentioning the induction motor parts of the picture, theoretical work system analysis and the relationship between the magnetic field strength with the working system of the induction motor.

The principles of work, the use and basic principles of an electric motor are essential and should be mastered by students majoring on Electrical Engineering. They should be equipped with a robust understanding of the concepts of electromagnetic fields. It is intended that later if they become teachers in respective area, they will be able to elaborate the concept to the students [7]. In addition, based on the observation at the vocational schools, it is believed that the induction motor is one of the topics that must be understood by students, of which the teachers are required to be able to explain to the students of vocational schools about the working system, how to use and detail parts of the electric motor in real context, not only through theory and images.

Based on the condition of this misconception, it requires real videos and practice applied to the Electrical Machine course, particularly for induction motor chapter. The rationale for selecting videos and real practices as the media for three-phase induction motor is based on some researches, such as a research carried out by Sababha et al, that they employed project-based learning to enhance the teaching of microprocessor-based embedded systems course to undergraduate students. The goal was to expose engineering students

to real-world problems and give them opportunity to apply what they have learned in the classroom [8]. In addition, Pablo et al also designed the educational project associated with teaching methodology [9].

The preferred learning model which is believed to improve students' understanding upon the three-phase induction motor in terms of electromagnetic induction is a Problem-Based Learning (PBL) model. In accordance with Malan's et al research, PBL model has created a positive condition for learners to develop self-regulated learning skills, so as to make learning experience more meaningful [10]. Supported by Ahlam and Gaber, PBL is believed to increase self-confidence, critical thinking ability, and students' understanding [11]. Besides that, Alvarez et al, also have conducted a research on the evaluation of the use of two teaching techniques in engineering, namely the use of problem-based learning and cooperative learning models [12].

This research is intended to employ Problem-Based Learning (PBL) model through real practices and supports by animation video to improve students' understanding upon the working principles of three-phase induction motor. It is expected that the misconception about the working system of the electric motor can be repaired.

II. METHOD

This action research was conducted at Electrical Engineering Education Study Program of PGRI University of Madiun in East Java. Seventeen of sixth-semester students were involved as the research subjects for the action research. The use of Problem-Based Learning (PBL) model is based on the consideration that this model is suitable to be applied in electrical engineering education programs [14], and such technical education materials should provide many examples of problems or

projects [15, 16]. To support students' understanding, simulation videos were utilized. The simulation video consists the process of application to build a model from a real system [17].

Data collection technique was carried out through observation and tests. In this study, quasi-experimental method was employed with the design of one-group pre-test post-test design. The increase of ability of students' understanding was calculated by the statistical test of research using paired sample t-test.

III. RESULTS AND DISCUSSION

This subject was chosen based on the condition of student's conception of induction motor. The condition of student's conception about induction motor is showed in Figure 1.
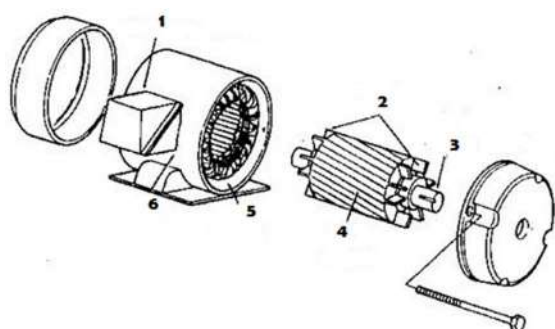
Figure 1. Induction Motor Construction
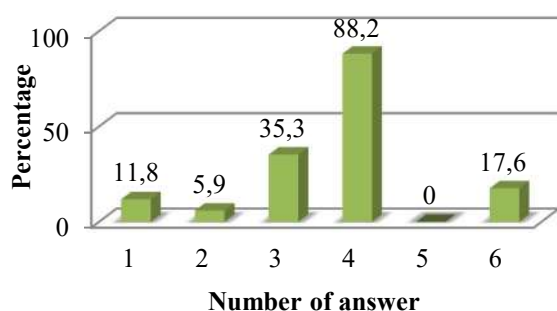
Figure 2. The Student's Presentation Graph about Induction Motor Parts

From Figure 2, there are 88.2 % of students are able to name correctly only the names of the induction motor parts at number 4, of which is the most easily known part of the induction motor that is the rotor.

Table 1. Results of Pre-test and Post-test

Indicators	Pre-test	Post-test
Students	17	17
Mean	47.71	67.17
Deviation standard	8.71	7.83
Minimum	35.00	65.00
Maximum	55.00	79.00

The normality test with Kolmogorov-Smirnov for pre-test value obtained significance of 0.565 and the post-test value obtained significance of 0.526, this means the value of significance is more than 0.05; it can be concluded that the values of pre-test and post-test were normally distributed. The homogeneity test based on Levene's statistic test gained significance of 0.674, which means the significance value was more than 0.05 that H_0 is accepted, indicating the variance of homogeneous data. Furthermore, due to the normal and homogenous data, parametric test with paired sample t-test was conducted as shown in Table 2. Based on the statistical test of paired samples tests, data for pre-test and post-test were obtained.

The results of statistical tests were analyzed by using SPSS 18 showing the value of Sig. (2-tailed) of 0.000, less than 0.05. It can be concluded that the statistical test H_0 is rejected. There are differences in the average between the pre-test and post-test for student's learning outcomes, which means that the effect of applying the Problem-Based Learning (PBL) model model occurs as part to improve the student's understanding upon three-phase induction motors in electromagnetic induction section. The data also show the mean paired

differences of -1.947, showing the average difference from the results of the pre-test and post-test scores. Significant influence can be seen in Table 1, the average post-test score is 67.17, which is better than the pre-test value of 47.71. Such effectiveness shows that the maximum score occurred after the learning process by employing PBL model of 79.00. The value of t-arithmetic is sig. 0.000, and as it is < 0.05, it can be concluded that H_0 is rejected because the mean of pre-test and post-test value is not equal (different). Thus it can be stated that the implementation of PBL model in the classroom influences the students' understanding. The mean of post-test score shows a value of 67.17, which is better than the pre-test value of 47.71.

In accordance with the research, the PBL model is believed to stimulate the students to actively participate and engaged in the learning process. The existence of listed phenomena in the form of contextualized problems displayed at the beginning of learning stage may encourage the students to think critically and try to solve the problems. Stages during the PBL model such as, exploring the issue, stating what is known, defining the issues, researching the knowledge, investigating the solutions, presenting and supporting the chosen solution, and reviewing your performance, give opportunity for the students to create innovations and solutions to their own experiences [18] based on the given problems. The PBL model helps to integrate knowledge and experience with new problems so that various solutions might be obtained in one learning process due to different analyses from the students.

Based on the results of the pre-test, it was known that most of students have not understood the concept of working system of the three-phase induction motor. From the problem number one, only the induction motor partnumber 4 (rotor) that could be identified correctly by 88.2 % of the students, while no students could mention correct answer for the other part number 5 which is electromagnetic stator. For the second question concerning on the working system of the induction motor, there are five important parts for the induction motor system, namely the electric current is passed through the wire; according to the Faraday's Law concept that when there is an electric current through the wire, it generates a magnetic field around the wire; as the magnetic field penetrates the rotor in the center of the electrically grounded wire, magnetic flux will arise in the stator; as a result of magnetic flux will give rise to magnetic torque, the energy is produced between the magnetic moment vectors of the coil with a magnetic flux density; and due to the existence of magnetic torque, the rotor will rotate following the Lorentz' Law. Of the five aspects, there were no single student could answer correctly for the third, fourth and fifth aspects. Students could notshow understanding on the concept of magnetic flux, of which mathematically is expressed in Equation 1.

$$d\phi = B.dA \qquad (1)$$

One student could not connect equation (1) with the working system of the induction motor. Based on these conditions, students were supported with the animation video exposing about the working system of the induction motor, and they were contextualized with the existing induction motor as the real equipment of practices.

After the students conducted the practice on the induction motor, it was obtained a better understanding of the concept particularly on the working systems of induction motor in relation with the electromagnetic field. The percentage of students' understanding on the working system of the induction motor is presented in Table 2.

Table 2. Percentage of Students' Understanding on the Working Principles
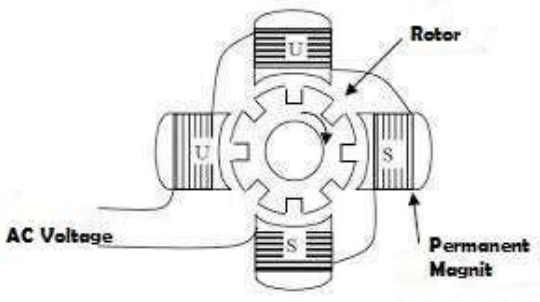**of a Three Phase Induction Motor**

Test	Aspects	Results		
		Before	After	N-Gain
1	**Electric current in the conductor wire**			
	Electrons from AC voltage sources flow through the conductor wire (the concept of electric current)	88.2 %	94.1 %	0.42
2	**Electric current generates a magnetic field**			
	The equation $B = \dfrac{\mu_0 I}{2\pi r}$ that proves that in induction electric current motors in conductor, wire generates a magnetic field.	35.3 %	73.3 %	0.56
3.	$d\phi = B.dA$ Where does the electric flux arises because there is a magnetic field that penetrates a certain area? Where is the rotor in the inducedmotor in the induction motor? 	0.00 %	47.1 %	0.47
4.	$\bar{\tau} = NIA\hat{n} \times \vec{B}$ The energy to drive an induction motor is a magnetic torque. Based on the equation, it is obtained that the magnetic torque is the energy generated by the vector of the magnetic moment of the coil with the magnetic flux density.	0.00 %	58.8 %	0.52
5.	Magnetic torque moves the motor withthe direction according to the principles of Lorentz's Law.	0.00 %	41.2 %	0.49

Table 1 describes the conceptual understanding of the students upon the working system of the induction motor. Based on the theory of the induction motor, the schematic of the working principles of an induction motor is shown in Figure 1. Figure 1 shows that the induction motor operates on the basis of electric induced electromagnetic induction.

Under Faraday's Law, an electric current can produce a magnetic field. In the induction motor, the application of Faraday's Law is clear, where the electric current flowing on the conductor wire will result in the magnetic field around the wire. This magnetic field then generates magnetic flux as it penetrates the rotor portion of the induction motor [19].
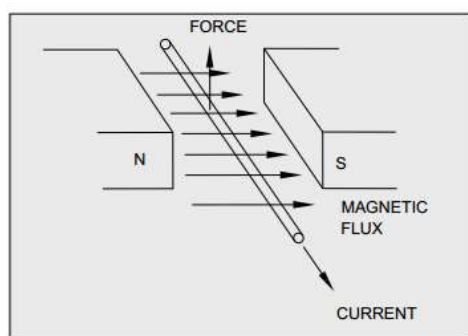
Figure 3. Force on a Conductor in a Magnetic Field

A new explanation to the effect of electromagnetic induction is proposed, while simultaneously rejecting the currently accepted induction law [20]. The electromagnetic induction device uses the kinetic energy of reciprocating motion of the MR damper which is converted into electric energy. The conversion proceeds according to Faraday's Law which expresses the phenomenon experimentally [21]. The mathematical form of Faraday's Law is presented in Equation 2.

$$e = -\frac{d\psi(t)}{dt} = -N\frac{d}{dt}\left(\int_S B.dS\right) \qquad (2)$$

Where Ψ is magnetic flux linkage through the area of coil cross section **S**, N is the number of turns, **B** is the magnetic flux density and e is the induced electromotive force (in volts). The minus sign is a manifestation of Lenz' Law which states that the sense (clockwise or counter clockwise) of the induced electromotive force created by the change in the magnetic flux must be such as to oppose the change producing it. As it is set in Equation 3.

$$d\psi = Nd\phi = NB.dS = NBdS\cos\varphi \qquad (3)$$

where φ is the angle between **B** and d**S**. In the case of time changes in the magnetic flux density **B**(t), equation (2) can be rewritten in Equation 4.

$$e = -N\frac{d\phi}{dt} = -NS\frac{dB}{dt} \qquad (4)$$

Thus, the Faraday's Law states that the induced electromotive force in the coil equals to the negative of the time rate of the magnetic flux changes through the coil. In other words, relative motion between the coil and permanent magnets of the considered device causes a change of the magnetic flux that induces an electromotive force in the coil. This force can also be regulated by the number of turns of winding in the coil or the intensity of permanent magnets.

An induction motor works using the principles of electromagnetic induction. The magnetic field on the induction motor comes from the electric current flowing through the conductor wire in the motor. In this case, the induction motor used is a three phase induction motor, which uses three types of windings in the motor. Each winding will give effect to the electromagnetic field. The electromagnetic field of each winding through the rotor causes an electric flux, which then causes the motor moving due to the magnetic torque based on the Lorentz' Law.

The concepts of magnetic flux, torque, and the Lorentz' Law in relation to induction motors previously could not be properly understood by the students. After the treatment of providing an animated video about the induction motor working system along with real and direct practices of disassembling the induction motor, the students' understanding was observed increasing. It is suggested that the most of the students majoring on the Electrical Engineering Education require real pictures and modeling of the working system of a strong current electric machine (induction motor). Positive changes were also observed at the time of the students executing the learning practice activities.

The implementation of such PBL model, the learning about electromagnetic induction topic can be carried out in a more efficient and effective manner. In addition to the current belief, Physics learning which has been considered difficult will be a little easier for the students by utilizing Problem-Based Learning (PBL) model.

IV. CONCLUSION

The results of this study show that the concepts of working principles of a three phase induction motor in relation to electromagnetic induction can be more easily understood by the students as it is presented by using Problem-Based Learning (PBL) model with the assistance of animation video and direct practice of disassembling of the three phase induction motor. Both animation video and direct practices are believed to improve students' understanding of the working principles of the three phase induction motor. The increase of the students' understanding upon the working principles of a three phase induction motor was perceived as medium gain category. The implementation of PBL model is believed to help the students improve problem-solving abilities, relate learning experiences with problems, improve understanding, and train to conduct investigations.

ACKNOWLEDGMENT

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