Magnetic force learning with Guided Inquiry and Multiple Representations Model (GIMuR) to enhance students' mathematics modeling ability

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Abstract

The magnetic force is one of the concepts in physics that need good mathematical modeling and representation ability to understand. This article presents new learning model to help the student understand this concept with various representation, knowing by doing, and accommodate their mathematics modeling ability. GIMuR model has five phases, namely: (1) Organization and orientation, (2) Sequence and hypothesis, (3) Investigation, (4) Representation, and (5) Evaluation and reflection. The analysis focused on the effectiveness of GIMuR model, the activities of teachers and students during learning, and how mathematical modeling of students and their representation in understanding the magnetic force. The effectiveness of the GIMuR model was tested using a t-test with one tail. Quantitative data in the form of test results and observation of learning implementation while qualitative data in the form of student interviews. The research results indicate that: 1) learning magnetic force by using GIMuR model effectively to improve students' mathematical modeling ability; 2) teacher and student activities in all step of GIMuR model were good categories in rate; 3) teacher should back to basic concept of vector rules before using various hand rules and guided student to reveal the problem in the form of field line diagram sketch and formulas as a way to train students' thinking skills. These results showed that GIMuR could be an alternative model in magnetic force learning and enhanced students' mathematical modeling ability.

Keywords: Guided Inquiry with Multiple Representations (GIMuR), Sequence, Magnetic Force, Vector Concept, and Mathematical Modeling Ability.

Introduction

The most important thing in physics learning is how to help students to understand the basic concepts of physics to use them flexibly in solving daily life problems (Shin & Phang, 2012). Learning is a process with many factors involved. One such factor is using the learning model (Oliver & Oesterreich, 2013; Pritchard, 1998). Conformity with material characteristics becomes one of the keys to the success of applying the learning model (Pritchard, 1998; Sund & Trowbrigdge, 1973)

In studying physics, the magnetic field is an interesting phenomenon and close to everyday life. Several studies have discussed students' difficulties in understanding

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magnetic fields primarily in the concept of magnetic force (Ambrosis & Onorato, 2013; M Saarelainen, Laaksonen, & Hirvonen, 2007; Scaife & Heckler, 2010). The most common difficulty encountered is the determination of the direction of the magnetic force (Fatmaryanti, Suparmi, Sarwanto, & Ashadi, 2017a). More specifically, students are not used to cross-vector operations and are too abstract to visualize vector directions (Scaife & Heckler, 2010). In the early stages of the study, we observed that a large number of students made "sign errors" when determining the direction of magnetic force. The concept of magnetic force direction perpendicular to the velocity and magnetic field is not followed by the concept of vector multiplication (Fatmaryanti et al., 2017a). Marking errors in direction also occur in understanding the direction of fields, magnetic poles, and cross products (Kustusch, 2016; M Saarelainen et al., 2007). But there is still little research to assess students' understanding of the mathematical rules on which the rules of the hand are based on the concept of magnetic force directions.

All difficulties encountered related to how to describe the problem situation to obtain mathematical equations and represent mathematical answers in physical content or vice versa (Pospiech, 2012). Other studies have not discussed the abilities that students must have to express how mathematical equations are derived and selected relevant equations (Angell, Kind, Henriksen, & Guttersrud, 2008; Başkan, Alev, & Karal, 2010). For these reasons, students' mathematics modeling ability is needed to solve these problems.

Through mathematical modeling, students learn to rediscover concepts or laws that have been discovered by scientists. At first, students can create a simple mathematical model, then gradually do the test, formalize and generalize the model (Pospiech, 2012). Some studies found that student's mathematics modeling ability in Indonesia not as expected (Fatmaryanti, Suparmi, Sarwanto, & Ashadi, 2015a).

To solve the learning problems in magnetic concept and students' mathematics modeling ability, some learning model has been developed. In electric field concept, new learning model has been developing with active learning (Samsudin, Suhandi, Rusdiana, Kaniawati, & Coştu, 2016). As the electric field, the explanation of the concept of magnetism is very close to everyday life. However, the reality is more explanation of magnetism in mathematical explanation (Albe, Venturini, & Lascours, 2001; Fatmaryanti et al., 2015a) than finding the concept of the magnet itself. If we

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return to how scientists explain the concept of magnets, then all concepts always begin from the invention (inquiry)(Buck, MacIntyre Latta, & Leslie-Pelecky, 2007; Kock, Taconis, & Bolhuis, 2013).

Some representations can be used to make it easier for students to understand unclear concepts. The use of multiple representations in learning can provide many contexts for learners to understand a concept (Cock, 2012). In the Ainsworth (2006) study also stated that multiple- representation in learning is necessary to develop the concept and build students' scientific ability. According to (Kohl, Rosengrant, & Finkelstein, 2007) the use of multiple representations when solving problems affect learners' performance in problem-solving and can be used as a way to solve abstract problems.

In this paper, we look in detail at the innovation of learning model with optimizing students' mathematics modeling ability. We focused how to learn the magnetic concept in topic determine the direction of magnetic force by using mathematical modeling and explore student difficulties with hand rules and their understanding of mathematical modeling in solving problems.

Research Questions

The following questions are the frame of this study:

1. How are the effectiveness of magnetic force learning by using GIMuR model to enhance students' mathematical modeling ability?
2. How are the activities of teacher and student activities in all step of GIMuR model?
3. How are the students' ways in making mathematical modeling of magnetic force direction?

Literature Review

Guided Inquiry

The inquiry model that will be used in this research is guided inquiry. The guided inquiry has a strong theoretical foundation based on constructivist learning theory (Khulthau, Maniotes, & Caspari, 2007; Sund & Trowbrigdge, 1973). The inquiry

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process requires considerable abstraction, so there is a need to accommodate inquiry tasks according to the level of cognitive development of the child (Wenning, 2011). In high school students, the learning process can be done through inquiry that is by building knowledge and strategies obtained from elementary and junior high school. Their capacity for abstraction and independence increases (Khulthau et al., 2007). Through guided inquiry model, students have guided release responsibility gradually. The goal is as in preparation for learning, living, and working in society (Nivalainen, Asikainen, & Hirvonen, 2013; Wilcox & Lewandowski, 2016). In line with the above, the application of guided inquiry model to high school students is considered appropriate for the purpose of this study.

Describes the steps in guided inquiry learning as 1) identification and problem formulation, 2) formulating the hypothesis, 3) collecting Data through Experiments; 4) analyzing data, and 5) taking conclusion. The application of guided inquiry model in learning does give a problem that takes a long time and teacher will have difficulty in managing the class (Hsu, Lai, & Hsu, 2014; Pritchard, 1998). The difficulty of applying inquiry steps occurs in the step of formulating hypotheses and analyzing data (Emden & Sumfleth, 2014; Fatmaryanti, Suparmi, Sarwanto, & Ashadi, 2017b).

Multiple Representations

The ability of learners to represent concepts in different ways is an interesting topic in modern science and mathematics education. A particular idea or problem can be expressed in various forms of representation (Kohl & Finkelstein, 2008; Kohl et al., 2007). Physics as a science that studies the phenomena of nature requires the ability to represent different to understand the same concept or theme. Capacity to describe the physics process in multiple representations can help learners solve physically challenging problems. Therefore, the mastery of physics content can be seen adequately from the mastery of physics in a multi-representation, namely in verbal, mathematical, image and graphic representation (Dufresne, Gerace, & Leonard, 1997; Ivanjek, Susac, Planinic, Andrasevic, & Milin-Sipus, 2016)

Mathematics Modeling Ability

Learning physics will be more meaningful if the students play an active role in connecting real phenomena with laws and rules in physics both concepts and

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mathematics (Wenno, 2015). One of the main ways to bridge the understanding process is with mathematical modeling. Through mathematical modeling, students learn to rediscover concepts or laws that have been discovered by scientists. At first, students can create a simple mathematical model, then gradually do the test, formalize and generalize the model (Pospiech, 2012; Redish & Kuo, 2015).

Mathematical modeling ability in this research is focused in some indicator that has been developed based on multiple representations and characteristic of magnetic field concept (Fatmaryanti et al., 2015a, 2017b). The indicators are 1) revealed the problem in the form of field line diagram sketch, 2) revealed phenomena in formulas, 3) using the vector rules, and 4) proposed an alternative problem-solving.

Characteristic of Magnetic Concepts

In the study of magnetism, hand rules became pronounced, where cross products are used to describe numerous phenomena, such as the force on a charge moving in a magnetic field. Since it is one of the most common ways for finding the direction of a cross product, many researchers have speculated that poor performance on it (Knight, 1995; Kustusch, 2011; Scaife & Heckler, 2010).

Several studies have shown that in learning magnets, learners have difficulty in using relationships and models that are specific to magnetic phenomena (Saarelainen et al., 2007; Saarelainen, 2011). Learners can detect the presence of electricity indirectly through the senses, such as electric shock, electric spark, electrostatic repulsion and pull, but cannot feel the magnet in the same way. Other difficulties that arise are when dealing with problems solving and mathematical forms such as the use of vectors and integral calculus with the physics description on the concept of magnetic field and flux (Bagno & Eylon, 1997). The use of magnetic rules in various situations is also an obstacle to teach (Doughty, McLoughlin, & van Kampen, 2014; Dunn & Barbanel, 2000). These findings are also reinforced by the conclusion (Albe et al., 2001; Michelsen, 2015) that mathematical rules are used almost in all learning, which in turn makes the physics relationship understood only as a calculus operation.

Learning using GIMuR Model

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In this magnetic force learning, we use an inquiry learning model combined with multi-representation. The development of this model refers to the results of Carolan et al., (2008) and Tytler et al. (2013), which has developed a multi-representation framework in topic planning (I and F), involves the role of teachers and learners through the representation of learning materials (S and O) (Tytler & Hubber, 2015). The combination has been adapted to the findings of the identified problem of students' mathematical modeling abilities. Combining this model resulted in a new model of Guided Inquiry model with Multi Representation (GIMuR).

The consideration of using inquiry model with multi-representation is as follows: 1) according to Wenning (2011) Inquiry learning model is ideal for physics learning and in some research results have been proven to train students' thinking ability and improve learning outcomes of students (Fatmaryanti, Suparmi, Sarwanto, & Ashadi, 2015b; Sen & Yilmaz, 2016), 2) multi-representation learning models help to learn abstract concepts, facilitate learners in expressing their thoughts with various forms of representation and potentially encouraging learners to discuss each other (Cock, 2012; Fatmaryanti et al., 2017b; Kustusch, 2016). So with that consideration, GIMuR learning model is expected to improve the students' mathematical modelling ability.

Learning by Guided Inquiry with Multiple Representations (GIMuR) that applied in the classroom has five phases, namely: Organization and orientation, Sequence and hypothesis, Investigation, Representation, and Evaluation and reflection. The phases of GIMuR models have the following steps as seen in Figure 1 with some supporting theory.

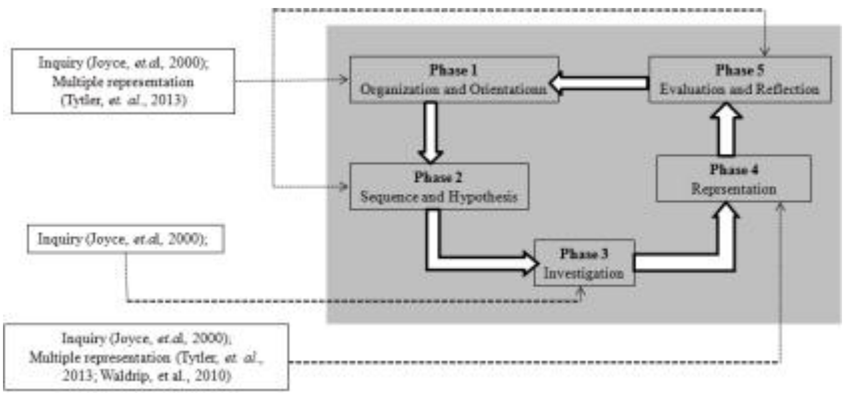

Figure 1. Syntax of GIMuR model with its supporting theory

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Methods

Research Design

In this study, the research design was using the randomized static group comparison design with experimental class and control class. The effectiveness of GIMuR model was tested by using t-test with one tail. There are two types of data in this research that is quantitative and qualitative data. Quantitative data in the form of test results and observation of learning implementation while qualitative data in the form of student interviews.

Population and Sample

The population consisted of 128 senior high schools' students of Grade XII in Purworejo, Central Java, Indonesia. The sample was selected by using random cluster sampling. There were 62 (38 female and 24 male) students who divided into experimental class (with N= 32) and control class (with N=30). Students in the experimental class were treated with GIMuR model, and those in control class were treated with traditional learning model. To get deep analyze about students' magnetic force conception, we used interview section with 18 students from the experimental class (11 female and 7 male) that were selected by randomizing.

Research Instrument

The data were obtained using testing, observation, and interview. A set of test was used to know the effectiveness of GIMuR model to increasing students' mathematical modeling ability related to the magnetic concept.

The test consists of 15 multiple choices questions with reason based on four indicators of mathematical modeling ability. The concept consists of magnetic force from moving charge and straight current wire in homogeny magnetic field. The test has been tested using product moment correlation and KR-20 with the result of reliability 0.86. Example of question from indicator revealed the problem in the form of field line diagram sketch could see in Table I.

Table I. Example of question from the indicator of mathematical modeling ability

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<table>
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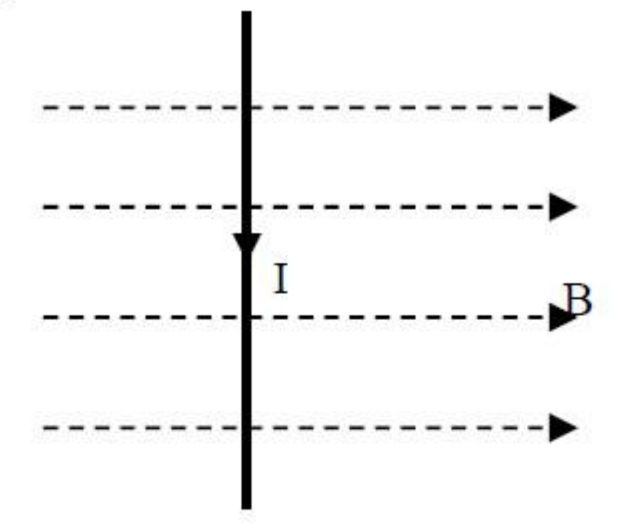
Revealed the problem in the form of field line diagram sketch

A wire is in the magnetic field as in the picture. Where does the magnetic force move on the wire to you?
A. Away
B. Approaching
C. Go right
D. Go left
E. Go up
Give your reason



</td>
<td>This case is a straight current wire which is inside the magnetic field, and the students have observed variations of direction B and I. Variations in the use of hand rules and how the students give the reasons for the rules are the guidelines for assessment</td>
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Revealed phenomena in formulas

A charge Q moves with velocity v entering an area containing magnetic field B and electric field E. If the charge is not affected by either magnetic force or electric force, what is the value of the ratio of the strength of the magnetic field and the strength of the electric field in that place!

A. QE/V
B. QV/E
C. QE/QV
D. Q/QV
E. QV/Q

</td>
<td>Students can connect the concept of electric field that has been obtained with the concept of magnetic field by using mathematical, sketch and verbal representation</td>
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The observation was used to know the implementation of GIMuR model from the teacher and student activities. There were two observers. Observation sheet is containing a checklist of activities in each phase of syntax GIMuR model. A brief explanation of teacher and student activity at each phase can be seen in Table II.

Table II. Teachers and Students' activity at each phase of GIMuR Model

Phase	Teacher Activities	Student Activities
Orientation and Organization	- Provide a case that raises students' curiosity - Guide students to identify problems from topics to build student representation	- Students give their opinions on cases given by teachers with enthusiasm - Students use various representation in describing their opinions
Sequence and hypothesis	- Provides a representational challenge to generate ideas in formulating a temporary answer - Guides the student to identify the variables that arise from the hypothesis	- Conducting literature review and discussing to formulate temporary answers to the problems faced - Identify the variables that arise from the hypothesis
Investigation	Guide students to carry out a step-by-step investigation, seeking clarity to build mathematical modeling abilities	Students search and collect data through libraries and experiments in groups
Representation	Guide students in representing the results of experimental analysis	Representing the results of experimental analysis in mathematical, image and verbal form
Evaluation and reflection	Helps students analyze and evaluate inquiry processes and their initial hypotheses	Make analyze and evaluate inquiry processes and their initial hypotheses in various forms of representation

To get in-depth analysis about students' mathematic modeling ability, we used the interview. We modify the question from studied of the representational and contextual problem (Kustusch, 2016). In this step, the interviewer asked a series of follow-up questions:

1. The rules that students use to determine direction of magnetic force

2. The result of multiplication of various directions vector

Data Analysis

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Descriptive statistics and inferential statistics were used to analyze the data of achievement test by using SPSS-20 package program. Normality and homogenously were controlled by using descriptive statistics. As for inferential statistics, independent samples t-test was used at the end of this study. This test was also employed to see the significant difference between groups.

The results of observation were analyzed by describing the teachers and students activities using frequency, percentage and mean. These activities were dealing with implementation of each step of GIMuR models. The observation was done by two observers. The assessment criteria were obtained by comparing the average scoring result from the two observers with the criteria of assessment in Table III.

Table III. Criteria of The Observation Assessment

Interval	Criteria
$3.2 < x \leq 4.00$	Very good
$2.75 < x \leq 3.25$	Good
$1.75 < x \leq 2.75$	Poor
$1.00 < x \leq 1.75$	Very poor

The result of interviews was used to get information about students' ways of making mathematic modeling of magnetic force direction. This finding was used to evaluate and reflect the implementation of GIMuR model, especially in mathematical modeling in magnetic concepts.

Findings

Results of effectiveness on GIMuR Model

Data of posttest score of mathematical modeling ability of experiment and control class were analyzed by mean difference test. This test was obtained from improving students' mathematical modeling ability using posttest score with t-test Independent Sample. As seen from Table IV, t value was 2.390 with degrees of freedom df = 59. With a fault rate of 0.05 and ttable= 2.000 so it is concluded that there is a significant difference between the experimental class and the control class. This shows that in learning by using GIMuR model effectively to improve students' mathematical modeling ability.

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Table IV. Independent sample t-test results of both treatment class

		Levene's Test		t-test		
		F	Sig	T	df	Sig.(2-tailed)
Posttest	Equal variances assumed	.009	.924	2.390	59	.020
	Equal variances not assumed			2.392	58.983	.020

Various forms of representation also arise during the process of investigating the concept of magnetic force. The example of student answer can be seen in Figure 2.

Note the direction of the current, the direction of the magnetic field and the direction of wire deviation will create a specific pattern and relationship. Can you link your findings to those rules? Give your explanation.

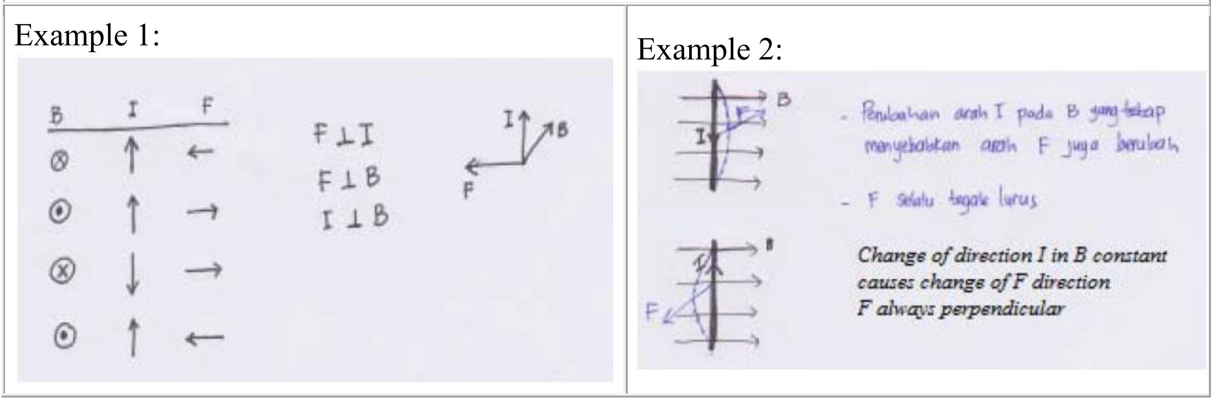

Figure 2. Example of students' representation in making conclusion

In the GIMuR model, students were trained to represent answers in various forms. Mathematical equations are not placed or become the first question. As in Figure 2, students do not directly use the rules of cross-vectors in determining the direction of the magnetic force, but through direct observation at the investigation stage. Learners perform a variety of variations of electric currents and magnetic field relationships. How students in drawing observations were varied, including how to summarize the results of the investigation. Figure 2 shown there were 3 forms of representation made by students that were image, mathematics and verbal.

Results from quantitative observation on learning activities

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The results of observation of the learning activities conducted by teachers and students for two meeting are presented in Table V. All activities are grouped and reviewed based on the steps of the GIMuR model.

Table V. The mean scores of teachers and students learning activity

Phase of GIMuR Model	**Teacher activity**		**Student activity**	
	1	**2**	**1**	**2**
Organization and orientation	3.25	3.62	3.00	3.25
Sequence and hypothesis	3	3.38	2.62	3
Investigation	3.38	3.62	3.12	3.62
Representation	3	3.25	3.00	3.25
Evaluation and Reflection	3.33	3.67	3.17	3.67

Based on Table V can be seen that the implementation of learning with GIMuR learning model with its components showed the value that tends to be stable at two times observation. In the second step, sequence, and hypothesis, the observation value of student activity tends to be lower than the other step.

In the early application of the GIMuR model the teacher still had difficulty in directing students to hypothesize and difficulty in providing appropriate representations of the material. For this reason, in this phase, the teacher is required to prepare the right form of representation before learning begins. For example, the teacher is trapped in giving the challenge of mathematical representation of magnetic field B relationship with electric current by directly directing the hypothesis to the mathematical relationship of the given keyword. To overcome this difficulty, the form of representational challenge is changed, into a representation of the direction of the magnetic field B with electric current I.

Results from in-depth interview on mathematical modeling in magnetic force concepts

After completing the test then at the next meeting conducted an interview. In the interview section, there was some finding.

Question 1: Student describes any hand rules of magnetic force that they used

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Right-hand rules were the predominant method for solving the direction of magnetic force. Every student explicitly used their prior physics knowledge to answer physics problems with the rule that usually use. From 18 students we found three type of hand rule as seen as Figure 3.

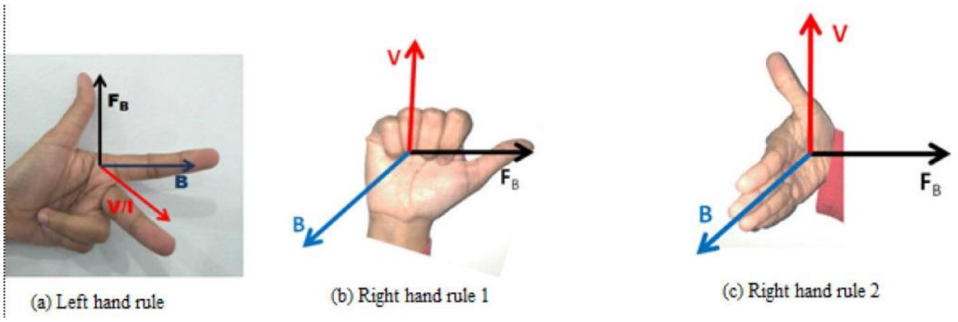

Figure 3. Types of hand rule usually uses in learning magnetic force

In detail, there are three students employed type (a), eight students used type (b), and seven students used type (c). Some participants relied primarily on one type of right-hand rules, such as Linda (type b) or Aisyah (type c). They said that known the rules from memorizing that they found from their high school teacher. In the in-depth interview, we also found that when students have been accustomed to one type, it will be challenging to learn magnetic force with another type. And many students do not know what the meaning of this rule is. As a result, when confronted with problems, many students become confused in applying.

The exciting finding is the reason from Nurul and Fafa, two students that use type (a). Actually type (a), is Fleming rules.

Nurul said, "I am not sure about this rules, but I think I can use this rule to find the direction of magnetic force with the direction of thumb."

Fafa said, "The direction of the magnetic force is perpendicular to B."

Interviewer "which direction is always perpendicular?

Nurul and Fafa, "All of them, F,B, i/v must perpendicular

The interviewer, "So, how about if B and i/v do not perpendicular with another or their angle is not 90°.

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Nurul and Fafa, "there is no F."

Question 2: Students' understanding of vector cross product

Many students reverse the order of vectors when performing hand rules; this question was used to determine whether they were aware of the non-commutative nature of the cross product. The interviewer asked, "are you using right-hand rule to find cross vector product?" Most students answered "No." They used multiplication of cross product and said that there is no difference in direction from two multiplications. But when the interviewer asked to explain with drawing vector direction, they become confused. From Figure 4 we can see that students do not understand the concept of multiplication of two vectors. In the left and right figure, the student has not been able to distinguish vectors' addition and multiplication. Meanwhile, the middle figure shows that direction of the vector has not been correctly right.

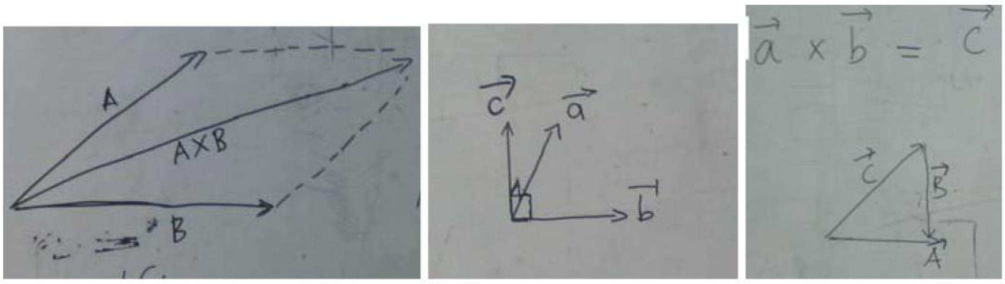

Figure 4. Example of students' answer in determine vector cross product

By examining the impact of physics features on correctness, this analysis has verified the results of (Scaife & Heckler, 2010) regarding the effects of field representation on student performance on magnetic force problems. Also, this analysis has provided clear evidence that the sign of the charge is also an issue for students something that has been only anecdotal until now.

Although performance on basic vector concepts was better than that on vector multiplication, students seem to have an innate sense of their knowledge about vectors overall, as evidenced by the disconnect between experience and performance (Barniol & Zavala, 2012; Knight, 1995). According to Knight, only one-third of the students entering a calculus-based introductory physics class had sufficient vector knowledge for mechanics, and 50% had no useful vector knowledge. However,

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(Nguyen & Meltzer, 2003, 2005) saw evidence that errors on basic vector operations were due, not to ignorance, but somewhat imprecise execution or confusion. They suggest that students have right intuition, but don't know how to apply their knowledge.

Discussion

From the first results found that GIMuR model is more efficient in increasing students' mathematics modeling ability than traditional learning. The results of the GIMuR model implementation are also in line with the research conducted by (Hettmannsperger, Mueller, Scheid, & Schnotz, 2015; Wong, Sng, Ng, & Wee, 2011) which concluded that multi-representation-based learning could improve understanding of physics concept (optics and mechanics) and help to clarify which kind of cognitive processes can be enhanced by which kind of representational learning activity. Then (Sunyono, Yuanita, & Ibrahim, 2015) said of the mental model that multi-representation-based learning can improve the teacher's mental model. The sequence step from GIMuR model can make significant differences in making hypothesis of the problem.

More specific research on the application of magnetism has been carried out by (Challapalli, Michelini, & Vercellati, 2013) which states that experimental inquiry-based applications are necessary for providing an understanding of the concept of the magnetic field to learners. It starts with the use of a compass and describes the direction and pattern of the magnetic field. The results of this study found that experimental inquiry-based experiments can improve students' thinking ability. This is in line with the GIMuR learning model which also implements guided inquiry and conducts investigations with experiments.

In the second result found that teacher and students' activities in all steps of GIMuR model have an outstanding category. In the inquiry, activities ensure the physical and mental participation of students in the learning process (Sen & Yilmaz, 2016). There was an exciting finding in the second step of GIMuR model. At the time of implementation second step, sequence and hypothesis are not as easy as the planning is made. At the first meeting, the teacher still difficulties in directing learners to make hypotheses and difficulties in providing appropriate representations with the material.

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These findings are not strange, because in other studies also found the problem that prospective teachers in Turkey also have difficulty in preparing hypotheses and teacher should spend more time focusing students on the conceptual aspects (Aydoğdu, 2015; Taasoobshirazi & Farley, 2013). For this reason, at the next meeting, the teacher is required to prepare the right form of representation before learning begins. Eventually, discussions between Physics teachers from several schools were conducted before the second meeting, to redefine the correct representation form for magnetic field learning.

In the third result found that how student builds the conception with their mathematics modeling ability. From questions 1 and two suggest that in the same problem but with different representation makes students confused. This finding was same with Heckler, et al. (2015) that as students have difficulty determining the direction of a vector; they also sometimes have trouble finding the magnitude of a vector from its components because of arrow representation. In a different context (vector addition), others have noted a misapplication of this theorem; it is unclear whether this misapplication was due to a difficulty with the concept of magnitude or with the addition operation (Barniol & Zavala, 2012; Deventer & Wittmann, 2007; Nguyen & Meltzer, 2003, 2005). Additionally, the same research suggests that students struggle with understanding cross products outside of any physics context, as well as in the context of magnetism and in other physics areas such as torque (Ambrosis & Onorato, 2013; Scaife & Heckler, 2011).

This error, too, was dependent on the representation of the field. For those given a problem with magnetic poles, this sign error was at least partly due to reversing the direction of the magnetic field (from south to north instead of north to south). However, (Scaife & Heckler, 2010) found that these sign errors were not systematic, indicating that there are multiple sources for this incorrect response.

From all these findings, given multiple representations in inquiry learning make student thinking how to find the concept and finally increasing student's mathematics modeling ability. According to Schonborn & Anderson's theory (2006) that the thinking process of students in learning science has three main factors, namely conceptual (Conceptual = C), Reasoning (R), and Mode representation (M). The ability of the representation of learners is strongly influenced also by the

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representation of teachers in implementing learning (Majidi & Emden, 2013; Waldrip, Prain, & Carolan, 2006). The sequence is done by adjusting the characteristics of the material to be learned (Waldrip et al., 2006).

Conclusion

This study contributes to the implementation of GIMuR model for abstract concepts and optimizes students' mathematics modeling ability. The teacher and student activity during the implementation GIMuR learning model are including a good category. The existence of sequence step helps students in formulating hypotheses students. As well as the representation stage, students' mathematical modeling ability is trained through the disclosure of observations with various representations. From deep interview can be concluded that 1) teacher should back to the basic concept of vector rules before using various hand rules, and 2) guided the student to reveal the problem in the form of field line diagram sketch and formulas as a way to train students' thinking skills.

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