Students learning difficulties in understanding the Lorentz force

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Abstract. Research has been carried out using the PIMCA learning model introduced by Cosmas Poluakan. The aims of this study is to describe the learning difficulties of the third semester students of Physics Education study program, in understanding the Lorentz force concept through learning using PIMCA learning model based on MR-SR (multiple representations - semiotic source). The research method is a descriptive analysis method, with the procedure beginning with giving a pre-test, then following the 4 stages of PIMCA learning. The results showed that the average of pre-test results was 7% and the average of post-test results was 37%. These results indicate that even though there is an increase in the average of mastery the Lorentz force concept, generally students still have difficulty in writing down the complete vector magnitude, determining the relationship of force, electric current and magnetic field in a three-dimensional coordinate system and also need to be given more time so that students more freely explore the concept of Lorentz force. The results of this study recommend that in order to understand the Lorentz force concept, the use of the PIMCA model needs to be accompanied by giving more practice questions, and doing virtual practicum.

1. Introduction

The abilities of each person in absorbing physics lessons different from one another. The fact that is often encountered is there are some students quickly understand the material and there are students who have difficulty and need time to understand the material. Students who cannot study well are called students who have learning difficulty. A learning difficulty may be said to exist in any situation where a student fails to grasp a concept or idea as the result of one or more of the following. Based on a research, there are still many students who experience learning difficulties due to difficulties in solving problems on questions, understanding concepts and formulas [1–3]. The physics lesson that is the focus of this research is the Lorentz Force. The concept of magnetism is one of the difficult concepts to understand in physics [4]. The results showed that most students failed to apply the right hand rule in determining the direction of the magnetic field and magnetic force [5–7]. This study aims to describe the learning difficulties of students in the Physics Education study program in understanding Lorentz's style using a new learning model introduced by Cosmas Poluakan, namely PIMCA (presentation, idea mapping, conceptualization, and formative assessment) [8]. This learning model is the development of the MOMBI (The Model of Model-Based Instruction) learning model, which was developed from Vygotsky's cognitive theory. Vygotsky defines ZPD (Zone of Proximal Development) as the distance between actual development as determined by an independent problem and the level of potential development determined through problem management under adult guidance or co-operation with more capable colleagues [9]. ZPD is used to describe the level of development of this learner or actual and
the next level, which can be reached using semiotic and environmental mediation tools and adults capable of peer facilitation [10].

Physics is closely related to Semiotic Resources. As in the Lorentz force concept, which uses symbols and images to determine the direction of the magnetic force and the magnetic field. One of the physics learning strategies that can support the use of semiotics is to use the Multiple Representation approach. Based on research, learning with a multiple representation approach is effective in improving students' conceptual understanding [11–14]. PIMCA is a learning model based on Multiple Representation - Semiotic Resources which is expected to make it easier to understand physics concepts, especially the Lorentz force.

2. Methods
The study was conducted at Department of Physics, Manado State University. The respondents are 30 students from third semester of Physics education study program. The research method that using in this study is descriptive analysis method. The test was paper and pencil test and the test instrument consist of 3 numbers based on semiotic resources that have been previously validated. The procedure beginning with giving a pre-test, then following the 4 stages of PIMCA learning (1) Presentation, which is the stage where students get initial information through presenting various forms of representation. This stage can be a combination of provocation steps and preconception of the MOMBI model, (2) Idea Mapping, which is the stage where students formulate concepts and build conceptual fabrications based on information received from various forms of representation. At this stage the concept map that students have built may not yet be mature. (3) Conceptualization, namely the stage where students receive information and are accompanied by instructional assistance, so that the scaffolding function can take place. At this stage, the mapping of immature ideas is corrected and constructed into correct concepts so that the misconceptions that occur later are not awakened. (4) Formative assessment, namely the steps to ensure that the concept of knowledge developed by students is correct. The formative assessment stage can serve as a scaffold assessment. Formative assessment can be used as the basis for diagnostic work.

3. Results and discussion
The results of this study are presented on the histogram figure 1 below.

![Figure 1. Histogram pre-test post test.](image)

The results of the research on question number 1 showed that 76.7% of students could not describe the direction of the Lorentz force on a positive charge, and only 6.7% of students could write the Lorentz force vector notation correctly. In question number 2, 23.3% of students could not describe the direction of the Lorentz force acting on a positive charge, and only 3.3% of people could write the Lorentz force
vector notation correctly. In question number 3, students were asked to describe the relationship between the direction of the Lorentz force, magnetic field, and electric current in 3-dimensional coordinates and the result was 43.3% of students could not describe the direction of the Lorentz force on the positive x axis, 30% of students could not describe the direction of the magnetic field on the positive z-axis, 30% of students cannot describe the direction of electric current on the positive y-axis. In writing vector notation, 6.7% of students could write Lorentz force vector notation correctly, 13.3% of students could write magnetic field vector notation correctly, and 6.7% of students could write magnetic field vector notation correctly. The results showed an increase in the average proportion of mastery of the Lorentz style concept by 30%. Even though there is an increase, these results are still relatively low and indicate that there are learning difficulties in students in learning Lorentz style material. Based on the research results, the difficulties students still experience in general are in determining the direction of motion of charged particles in a homogeneous magnetic field. In fact, students already had the initial concept that when a particle enters a magnetic field, its motion will be deflected. However, the understanding of how the direction of movement of the load has not been fully mastered by respondents, this is similar to research that has been done before [15]. Other learning difficulties are also found in determining the direction of magnetic forces, magnetic fields and electric currents in 3-dimensional coordinate systems. Right Hand Rule is often used in determining the direction of 3-dimensional vectors [16]. The Lorentz force is a physics concept that uses 3-dimensional coordinates in which the right-hand rule is often used to determine its direction. Right hand rule application Improper rules in solving physics problems can cause failure to use these rules [17] and make student misunderstanding.

4. Conclusion
These results indicate that even though there is an increase in the average proportion of mastery of the Lorentz force concept, generally students still have difficulty in writing down the complete vector magnitude, determine the relation of force, electric current, and magnetic field in right hand rule practice. The results of this study recommend that in order to understand the Lorentz force concept, the use of the PIMCA model needs to be accompanied by providing more practice questions, and doing virtual practicum.

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