Visualization Lorentz Force with Tea Leaves for Studying Magnetic Field in Senior High School

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Abstract. The purpose of this study is to visualize the motion of the Lorentz force using tea leaves for learning magnetic fields in high school. Based on assessment needs results of students who attend school in Jakarta, 56.7% of students have difficulty determining the direction of the Lorentz force, 95% of students have a better understanding of the direction of the Lorentz force if it can be visualized. This research uses the R&D method, which refers to the ADDIE model. The Lorentz force visualization (Vigalo) consists of a power generator, tea leaves, two copper wires, two neodymium magnets, and an adjustable voltage source of 1.5 volts - 6.0 volts. The two permanent magnets are placed separately at a distance of 2 cm and able to produce a magnetic field of 88.6634 Gauss. The voltage source is connected to the experiment box and can see the movement of tea leaves and visualize Lorentz force direction lines that match the right-hand rule. This experiment shows that visualization Lorentz force with tea leaves can be used in learning magnetic field material in senior high school.

1. Introduction
Physics is one of the branches of science that is developing in science and technology (IPTEK) which can educate students to have intellectual and religious attitudes in life and study daily activity phenomena, so that learning physics requires activities in the form of observations or experiments [1]. In high school, students need to improve multi-representation skills include verbal skills; visual skills such as pictures, charts, diagrams, tables, graphs; symbolic skills are symbols [2], codes, symbols [3], and mathematical skills are equations or formulas [4]. Therefore, students are required to be able to face changes in all fields, act based on logical thinking, think critically, creatively, and innovatively [5].

The level of understanding of students in basic physics learning that fully understood can be categorized as low [6]. One of the physics learning materials that are abstract and difficult for students to understand is electricity and magnetism [7]. Some students have misconceptions in presenting magnetic field lines and the direction of the Lorentz force [8]. There are misconceptions in understanding the Lorentz force and magnetic field include determining the direction of the magnetic force, magnetic field, and determining the direction of electric current using the right-hand rule [9]. In addition, the difficulties faced by students in studying magnetic electricity are that students often experience errors in distinguishing between magnetic and electric forces, students have difficulty in determining the direction of the magnetic field on electric charges, students have difficulty in applying the concepts of electric fields and magnetic fields and students have difficulty knowing changes in the magnetic field. Magnetic flux and implement Faraday's law and Lorentz force [10]. Therefore,
learning media is needed that can be understood by students regarding the concept of the Lorentz force.

The first step in this research is to analyze the needs of teachers and students in schools. Based on the results needs analysis on physics teachers from Jakarta and Bekasi areas, it starts learning media, one of which was teaching aids, helped deliver subject matter and help students understand the concepts. But there is not enough teaching aids in schools to be used in physics learning. In the analysis of learning media needs with the number of respondents 60 students randomly in schools in Jakarta and Bekasi that 61.7% have difficulty understanding the Lorentz force material, 56.7% of students have difficulty determining the direction of the Lorentz force, 65% didn’t understand if only explained by teacher, and only 10% of learning in schools that used teaching aids as learning media. As many as 95% of students think they understand more about the direction of the Lorentz force if it can be visualized and seen direct so that students agree on the development of teaching aids that can visualize the direction of the Lorentz force for magnetic field learning. The following is the data from the needs analysis by respondents:

| Aspects                                      | Percentage |
|----------------------------------------------|------------|
| Difficult to understand the Lorentz force     | 61.7 %     |
| Difficult determining the direction of the Lorentz force | 56.7 %     |
| Not understand Lorenz force if only explained by teachers | 65.0 %     |
| Using media for learning                      | 10.0 %     |
| Need visualization to learn Lorentz force      | 95.0 %     |

Respondents agreed that visualize the motion of the Lorentz force can help students understand the magnetic field to motivate student learning in schools. The development of Lorentz forces the name is Vigalo can visualize the phenomena of the movement of charged objects due to the interaction between electric and magnetic fields that can be applied to learning magnetic fields in the class. The purpose of this research is to visualize the motion of Lorentz force with tea leaves for learning physics in senior high school, especially on magnetic field material.

2. Method
The method used is Research and Development (R&D) using the ADDIE research model. The stages in the ADDIE model are Analyze, Design, Develop, Implement and Evaluate [11]. The ADDIE model has a simple step [12] and there is an evaluation at each step [13]. The first step is preliminary research, including analysis of student needs and analysis of teacher needs regarding learning media, teaching aid facilities in schools, and difficulties in studying the Lorentz force. Needs analysis using a questionnaire. The second step is to design 2D regarding the development of learning media need in schools. The third step is to develop Lorentz force props or called Vigalo (visualization of Lorentz force). The design of the experiments shown in figure 1.
Figure 1. Set experiment Vigalo (visualization Lorentz force)

Figure 1 shows that set experiment Vigalo (visualization of Lorentz Force). Developments in the Vigalo props include tea leaves to visualize the movement of particles when there is an interaction between electric and magnetic fields, power generation using batteries, baby oil liquid, copper wire, and neodymium magnets. The power generator used a high voltage inverter to increase the voltage source. The voltage source used batteries 2 x 1,5 volt plus 9 volts. The fourth step is testing the Lorentz force Vigalo. The props developed can show the interaction of charged objects in electric and magnetic fields. Tea leaves as a charged object when interacting with electric and magnetic fields will move in a direction that is by the right-hand rule, so this teaching aid can visualize the concept of the Lorentz force. The fifth step is an evaluation of the teaching aids that have been developed.

3. Result and Discussion

The Lorentz force teaching aid was developed using a 10 cm x 5 cm x 5 cm experimental box with acrylic materials, a power generator, red and black wires, two copper wires, baby oil, tea leaves and two neodymium magnets assembled as shown in the figure 2.

Figure 2. Kit experiment before installation

The power supply has components, including a battery, a motor speed controller to adjust the desired voltage between 1.5 volts to 6.0 volts, an on/off switch, red and black binding posts, and a digital voltmeter to see the voltage and current. Figure 3 showed that the kit experiment after installation. The Vigalo teaching aid experiment was divided into two activities: before being given a neodymium magnet and after being given a neodymium magnet. The following are the results of the experiment before being given a neodymium magnet.
In Figure 4, when the tea leaves are sprinkled into the box experiment without an electric current, the tea leaves will remain motionless, which means that the tea leaves are at no charge. After being given a voltage, the tea leaves will move like charged particles. The motion of the tea leaves form the lines of the electric field because the electric field moved from high potential (+) to a low potential (-) and the magnetic field lines are form see in figure 5.

The second experiment used two neodymium magnets placed at the top and bottom in the box experiment. The results of measurements using a gauss meter, the magnitude of the magnetic field at a distance of 2 cm is 88.6634 gauss. Put a north magnet under the experimental box and a south magnet above the wires with a distance of 2 cm. Current flows from positive (left) to negative (right). The magnetic field is north to south (upward). The voltage is given from 1.5 volts to 6 volts. Tea leaves will move faster if given a large electric voltage.

In Figure 6, after being given a magnet and before an electric current is applied, the tea leaves remain stationary. The tea leaves do not go up to stick to the magnet because the nature of the tea leaves is diamagnetic, it cannot be attracted by a magnet. In Figure 7, when the copper wires are an electric field, the tea leaves that were previously silent will move from high potential (+) to a low potential (-) because it is affected by a magnetic field from the north (bottom) to the south magnetic field (top). Lorentz's force is directed towards the observer in figure 8. So that the tea leaves will move towards the observer. The direction is following the right-hand rule. The thumb as the direction of the electric current goes to the right, the other fingers as the magnetic field from north to south point up, then the Lorentz force will go to the observer. Therefore the tea leaves will move obliquely towards the observer see figure 9.
In the third experiment, the south pole is placed under the box experiment and the north pole is placed above the box experiment. The current flows from positive (left) to negative (right) and the magnetic field is north to south (downward). The voltage given is from 1.5 volts to 6 volts, which can be adjusted by turning the motor speed controller and can be seen on the voltage display. The greater the electric current is given, the faster the movement of the tea leaves.

When the tea leaves are magnetized and before an electric current is applied, the tea leaves remain stationary. When a copper wire is electrified, the previously stationary tea leaves will move from high potential (+) to a low potential (-) because it is affected by a magnetic field from the south (bottom) to the north magnetic field (top) so there will be a Lorentz force whose direction is away from the observer. Illustration in figure 10. So the tea leaves will move away from the observer. This direction is following the right-hand rule. The thumb as the direction of the electric current goes to the right, the other fingers as the magnetic field from north to south point down, then the Lorentz force will move away from the observer. Therefore the tea leaves will move obliquely away from the observer see in figure 11.

This experiment is to visualize the direction of the electric field and the Lorentz force using tea leaves. In the first experiment, the direction of motion of the tea leaves can visualize the direction of the electric field. In the second and third experiments, the direction of motion of the tea leaves can be
turned because it is impacted by electric and magnetic fields. So that the Vigalo props can visualize the direction of the Lorentz force using tea leaves according to the right-hand rule. Vigalo can help students determine the direction of the Lorentz force. Students can be motivated in learning physics at school with learning media [14].

4. Conclusion

Based on the experiments, visualization of Lorentz force (Vigalo) is able to visualize the direction of the Lorentz force with tea leaves, used a voltage variation of 1.5 - 6.0 volts and two variations in the direction of the magnetic field. The deflection of the direction of the tea leaves is visualized according to the right hand rule. So that the Vigalo can be used in learning magnetic fields in high school.

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