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# Development of the Wimshurst Machine as a Learning Media on Static Electricity Material for Junior High Schools

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## Abstract

This research aims to produce a learning media development product in the form of a Wimhurst machine teaching aid that can be used by teachers and students in the physics learning process. This media is expected to improve the knowledge and scientific thinking skills of grade 8 junior high school students in physics lessons on static electricity. This research was conducted in March-June 2014 at the Physics Department Laboratory, FMIPA-UNJ. The research carried out is research and development. This machine (the media) can show electric charge jumps directly from the friction between aluminum foil (sector) and brass as a rake. The results of the Wimhurst machine are learning media in the form of teaching aids that can help teachers in conveying material and can develop science process skills. The results of testing the Wimhurst machine teaching aids can attract students' interest in studying static electricity, so that students can easily understand the concept of static electricity.

**Keywords**: learning media, Wimhurst machine, static electricity

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## INTRODUCTION

In the physics learning process, the use of learning media has become important, this is because physics is a subject that has quite complicated, abstract and imaginative discussions so students have to exhaust their minds to be able to understand a concept (Mambu et al., 2019). At a time when technological advances are currently developing, the visualization of the existence of applications of physics tools can be optimized to help students understand physics concepts at school (Suyatna et al., 2017). The use and development of learning media can arouse students' interest in being directly involved and can stimulate students to be active in the learning activities, and learning media, students can experience directly the new knowledge conveyed by the teacher. Furthermore, the use of media that incorporates daily phenomena can make physics learning more relatable and applicable to students' everyday lives. This can increase their motivation and engagement in the subject, as they can see how physics concepts are relevant and useful in real-life situations. Additionally, the use of technology and the internet in physics learning can further enhance students' understanding and engagement (Wieman et al., 2008).

Static electricity is often considered a difficult topic for students to grasp due to its abstract nature and complex concepts (Octavia et al., 2021). Students may have difficulty visualizing and understanding how charges interact and behave in static electricity (Saputro et al., 2018). This is due to the lack of appropriate learning media for explaining static electricity material. The learning media in this case are the teaching aids, which are often displayed in textbooks, usually plastic combs with wool cloth and glass with silk cloth (Amini & Fitria, 2019; Başer & Geban, 2007). Apart from that, the methods used by teachers at school still use conventional methods; as a result, students can only listen and see the teacher's explanations. This does not help students in describing the process of static electricity phenomena. The lack of learning media also affects students ability to describe basic concepts in static electricity. In the learning process, teachers usually talk about electrical events in everyday life, even though these events can be created by the teacher and involve students directly. Apart from increasing students' interest in the learning process, another reason this research was conducted was for future educational trends. Therefore, it is essential to develop learning media that can effectively explain and demonstrate static electricity concepts in a relatable and engaging manner for students.

The main objective of developing learning media for science learning, specifically for static electricity, is to enhance students' understanding (Humaira et al., 2019; Alkadri & Fauzi, 2020) and comprehension of the complex concepts associated with static electricity. By providing suitable and effective learning materials, students can engage in hands-on activities and experiments that allow them to explore static electricity phenomena firsthand (Shen & Linn, 2010; Obadović et al., 2007). Additionally, the development of learning media aims to improve students' cognitive skills and critical thinking abilities (Basar et al., 2020; Bao et al., 2019; Desfiyani et al., 2020). Furthermore, the development of learning media for science learning also aims to promote active learning and student engagement in the classroom (Priyanto et al., 2018). In order to effectively enhance physics learning, it is important to establish specific criteria for learning media used in the classroom. When it comes to teaching static electricity, the following criteria should be considered for developing effective learning media: interactive, visual representation, real-life application, incorporation technology, and promote active learning. These criteria will ensure that the learning media effectively engage students, make abstract concepts more tangible and relatable, and provide opportunities for students to actively participate in the learning process.

The learning media should allow students to engage in hands-on activities and interactive experiments related to static electricity. This will enable them to observe and experience the phenomena firsthand, fostering a deeper understanding of the concepts (Budiyanto & Widiastuti, 2018). Utilizing visual aids and demonstrations that effectively illustrate the behavior of charges in static electricity is crucial (Shen & Linn, 2010). This helps students overcome the abstract nature of the topic and comprehend complex concepts through visualization (Casperson & Linn, 2006). Learning media should incorporate real-life examples and applications of static electricity to make the concepts more relatable and applicable to students' everyday lives (Yuningsih et al., 2018) This can enhance their motivation and engagement in the subject. Integration of technology, such as simulations and interactive multimedia, can further enhance students' understanding of static electricity. Technology allows for dynamic and engaging demonstrations of abstract concepts (Raymond, 2016). Effective learning media should promote active participation and critical thinking skills among students. This can be achieved through activities that require problem-solving, experimentation, and analysis (Setyowidodo et al., 2017). By aligning learning media with these criteria, educators can create an enriching and effective learning environment for teaching static electricity in physics, ultimately enhancing students’ understanding and engagement with the subject.

The Wimhurst machine was made by James Wimhurst in 1883. The Wimhurst machine can produce electrical jumps based on the number of disks used along with the diameter used, as well as the distance between the disks. Small pieces of aluminum called “sectors” attached to the outer surface of the disk will help to drain excess electrical charge from the disk.

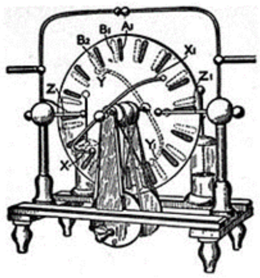

**Figure 1**. Wimhurst Machine

Using the right learning model can also increase the efficiency of the learning process. The hands-on activity learning model is one of the appropriate learning models in solving problems of difficulty understanding basic concepts, because the hands-on activity learning model requires all students to use several learning media and conclude a phenomenon that occurs when using them. Developing a static electricity learning media in the form of a Wimhurst machine to explain the process of lightning, and a hands-on activity learning model will be carried out in testing the Wimhurst machine learning media so that students can understand the basic concepts of static electricity phenomena in everyday life (Collazos et al., 2016; Ivanov & Nikolov, 2016).

## METHOD

This research method is a development model. The subjects of this research were eighth-grade junior high school students. This research was conducted at the Physics Mechanics Laboratory, Physics Department, FMIPA, Jakarta State University. This research is focused on developing learning media in the form of teaching aids. Development research is carried out through the stages of preliminary study, initial media design, media creation, media testing, media validation, media testing on teachers and students, and making reports. In the media validation process, if the media is not suitable, it will be reviewed from a manufacturing perspective and correct any deficiencies in the media.

## RESULTS AND DISCUSSION

### Analysis Stage

The initial needs analysis stage was carried out with the aim of finding out the needs and constraints of teachers and students in learning physics regarding static electricity. Identifying their needs regarding the creation of learning support media in the form of Wimhurst machines in junior high schools. Based on the results of the needs analysis questionnaire, it can be concluded that the majority of students like physics practicum, which can be seen from the results of the needs analysis questionnaire with a percentage of 88.52%. In practice, teachers very rarely conduct experiments, around 1-2 practicums in one semester. Then, based on the questionnaire, data was obtained that 100% did not know and use the Wimhurst machine, and 91.80% of respondents supported and were interested in the development of supporting physics learning in the form of teaching aids in the form of the Wimhusrt machine. Based on this data, it is necessary to have teaching media supporting physics teaching aids as an alternative learning media in junior high schools to support learning. With the production of the automatic Wimhurst machine, it is hoped that it will become a medium that supports students in learning junior high school physics.

### Learning Media Design

The manufacturing stage begins with determining the initial design of the static electricity learning media (Wimhurst machine). The initial design was based on developments in the Wimhurst engine as shown in Figure 2. The part of media design: (1) mica circle; (2) aluminum plate; (3) Wire brush (double); (4) Electrode Collector; (5) Leiden Jar; (6) Charge neutralizing comb; (7) Dynamo (8) speed control

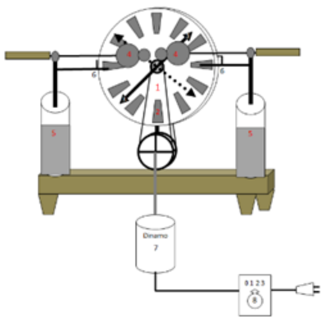

**Figure 2**. Learning Media Design

### The Process of Making Learning Media

The process of making learning media was carried out over 4 months. Making learning media is done by dividing the machine into several parts, namely (1) induction source part; (2) storing and releasing electric charges; (3) Controller. The induction source is made of circular acrylic material with a diameter of 23.6 cm, totaling 2, surrounded by aluminum foil, totaling around 20. The two acrylics are connected to a pulley with a silk belt, one of the belts is installed upside down so that it can rotate in the opposite direction. In this induction source there are also 2 pairs of rakes made of stainless steel and brass fibers as aluminum foil rakes. The total height of the induction source section is 30.5 cm.

**Figure 3**. Induction Source

**Figure 4**. Laiden Jar and Discharger Electric Charge

In the electric charge storage and release section there are several parts, including the Leiden Jar, charge neutralizer (collector) and electric charge release rod. The Leiden Jar is made from plastic in the shape of a bottle with a diameter of 4.93 cm and a height of 19.8 cm. Some of the inner and outer covers of the bottle are covered with aluminum so that it can store the charge from the induction source.

The neutralizer (collector) and release of the electric charge are made of stainless steel, in the neutralizer (collector) of the charge there is a pointed part which aims to attract the electric charge from the friction of the aluminum foil with brass at the induction source. In the electric charge release section there are two large balls and two small balls made of stainless steel, for the large size it has a diameter of 18.80 mm and for the small size it has a diameter of 8.84 mm, at the end of the charge release it is provided with plastic material so that when it is used students/tool users are not struck by electricity as a result of induction.

The controller section consists of a dynamo with a delta box type (full gear set) with an input voltage of 24 volts which is directly connected to the induction source with a silk belt. There is also an electrical circuit that provides a timer so that the turning machine can turn off automatically. On the controller button there is an on button and a potentiometer which is useful for adjusting the speed given to the induction source. With A speed of 17 rpm, B speed of 50 rpm and C speed of 70 rpm. The part where the electrical circuit and motor are located is provided with a hinge so that it can lock the box, which aims to provide security for the user.

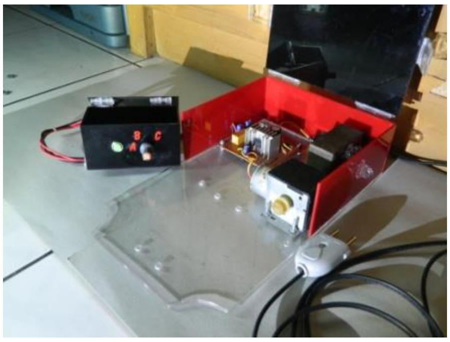

**Figure 5**. Dynamo and Rotation Controller

**Media Testing**

This prop has 20 pieces of aluminum foil on each 2 acrylic circles, with 2 scratching sticks made of brass. The way this tool works is that the acrylic disk rotates with the help of a dynamo and controller which have different speeds, so that the sector (aluminum foil) rubs against the brass rake.As a result of this friction, there is a change in charge in the sector. The excess electric charge in the sector is then channeled to the charge collecting electrode (Leiden jar) as a capacitor.

If the charge in the Leiden jar is full, the charges are directly channeled to the electrode release which is made of spherical stainless steel. The electric charges that have accumulated at the end of the ball create a very strong electric field that is able to polarize the surrounding air, so that it can attract electric charges from the end of the electrode ball to the other electrode ball.

**Figure 6**. Wimhurst Machine

This media has three (3) different speed variations, namely (1) speed A with a rotational speed of 18 rpm; (2) speed B with a rotational speed of 50 rpm; and (3) speed C with a rotational speed of 70 rpm. These three rotational speeds result in different jumps in the resulting electric charge. The following are the results of the experiments that have been carried out as shown in Table 1.

Table 1. The data of electrical jump for the variations of rotations's speed.

| # | Speed of Rotation | Number of Electrical Jump |
|---|---|---|
| 1 | 17 rpm | 0-3 time |
| 2 | 50 rpm | 10-11 time |
| 3 | 70 rpm | 11-13 time |

This is because, the faster the circle rotates, the friction that occurs between the aluminum foil and brass will occur more frequently compared to at a low speed, as a result the charge changes on the aluminum foil will be greater and the electric charge will jump more.

**Figure 7**. Electric Charge Jumps In Bright Conditions

**Figure 8**. Electric Charge Jumps In Dark Conditions

The distance between the discharge electrodes can also affect the number of electric charge jumps. On the discharge electrode the two distances can be adjusted. The teaching aids were tested at certain distances, namely 0.5 cm, 1 cm and 2 cm. The results of the props experiment are as follows.

**Table 2**. Results of electric charge jumps at different speeds with a distance between the electrode balls of 0.3 cm.

| # | Speed of Rotation | Number of Electrical Jump |
|---|---|---|
| 1 | 17 rpm | 1-3 Time |
| 2 | 50 rpm | 10-12 Time |
| 3 | 70 rpm | 13-17 Time |

**Table 3**. Results of electric charge jumps at different speeds with a distance between the electrode balls of 0.5 cm.

| # | Speed of Rotation | Number of Electrical Jump |
|---|---|---|
| 1 | 17 rpm | 0-3 Time |
| 2 | 50 rpm | 10-11 Time |
| 3 | 70 rpm | 11-13 TIme |

**Table 4**. Results of electric charge jumps at different speeds with a distance between the electrode balls of 0.8 cm.

| # | Speed of Rotation | Number of Electrical Jump |
|---|---|---|
| 1 | 17 rpm | 0 time |
| 2 | 50 rpm | 0 time |
| 3 | 70 rpm | 1-3 time |

The different total jumps are because the electric field produced will be smaller at greater distances, so that the electric charge cannot move as easily as when the distance between the electrodes is close to one another. All the experiments that have been carried out are also greatly influenced by the condition of the sector (aluminum foil) used, with very frequent use it can result in the sector being eroded, so that changes in the type of electrical charge in the sector are not as good as in the initial state which had not yet been eroded by the brass.

**Media Validation**

Media validation is carried out by media experts and material experts. Media expert validation was carried out at Taman Mini Indonesia Indah (TMII) and material validation was carried out at Jakarta State University (UNJ). The following are the results of media expert validation.

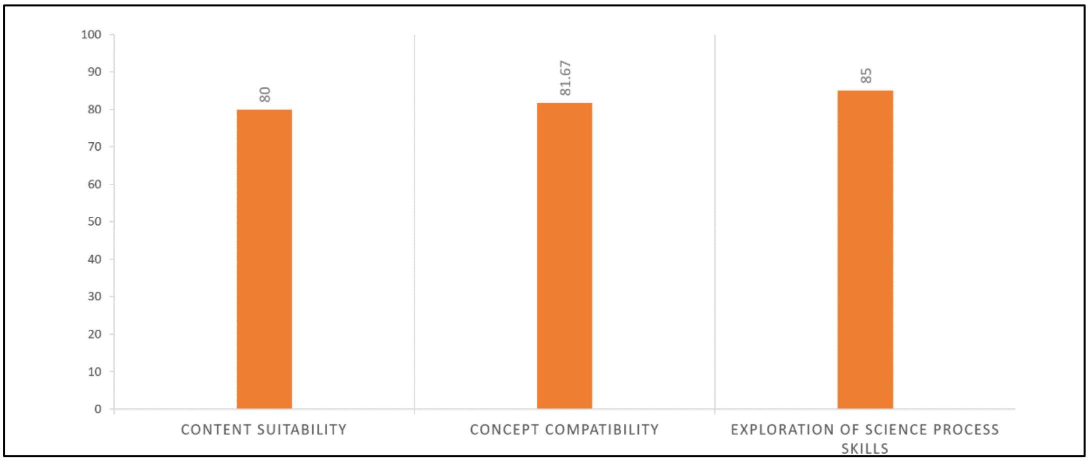


**Figure 9**. Material Expert Validation Results

Based on Figure 9, the three assessment aspects, including suitability of content, suitability of concepts and exploration of science process skills, obtained a very good assessment level, namely in the score interpretation range of 80-100% (very good). The following are the results of the validation from the material expert team.

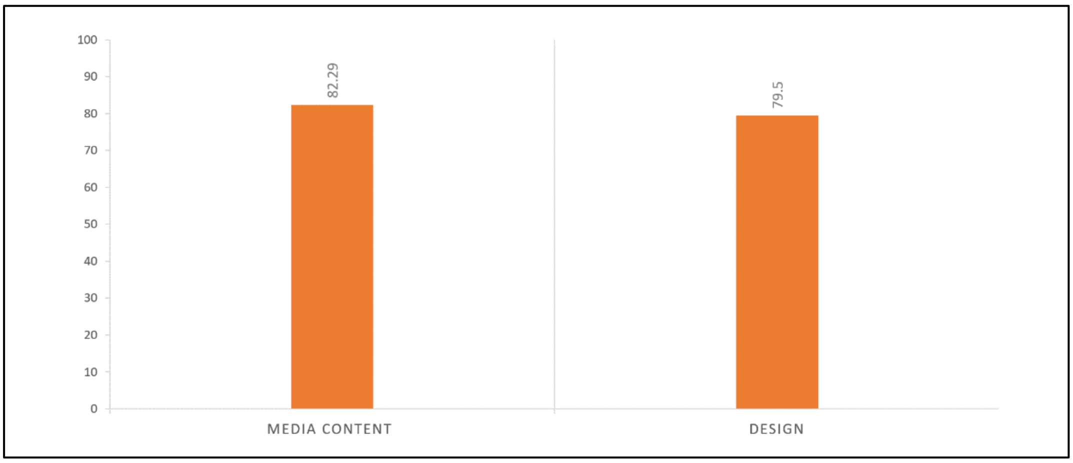


**Figure 10**. Media Expert Team Validation Results

Based on Figure 10, the two aspects of assessment, namely media content (content) and design, obtained a very good level of assessment on media content (content), namely in the score interpretation range of 80-100% (very good) and obtained a good level of assessment on product design with a range of 60-79.99% (good).

Validation of teaching aids is related to the suitability of core competencies in the 2013 curriculum and the use of teaching aids as learning aids in schools to help students achieve the core competencies that must be achieved.

The teaching aids that have been produced must be in accordance with the concept of static electricity and not give rise to misconceptions. Also, the props must be attractive, practical and easy to use so that they can attract students' attention when used in the learning process. The Wimhurst machine is expected to provide students with a more direct and concrete learning experience.

After validation tests were carried out by experts, comments and suggestions were obtained which would later be used by researchers to improve and add value to the Wimhurst machine trainer.Based on the material expert team, the suggestions given by the material expert team include:

1. Determine where the electrons that jump or splash between the two electrode balls come from
2. Develop an instrument to measure student competency in static electricity material in the form of a performance test
3. Equip the visual aids with a rotational speed measuring instrument so that you can see the relationship between rotational speed and load jump
4. Increase the rotational speed of the induction source
5. Provides more speed variations
6. Adding packaging (storage box)

Furthermore, based on the media expert team, the suggestions given by the media expert team include:

1. The safety aspect of the teaching aids is still not good
2. The durability of the tool is still not good
3. It should be demonstrated and equipped with other supporting scientific information
4. The production of props was developed by making them in larger sizes
5. Props are added with additional components that are even more interactive
6. Need to add an operation manual

**Media testing by teachers and students**

The validation of the Wimhurst machine for teachers was assessed from several aspects, including: suitability of content, suitability of concept, media content, design and scientific process skills of display media. Figure 11 shows the results of validation by experts (teachers).

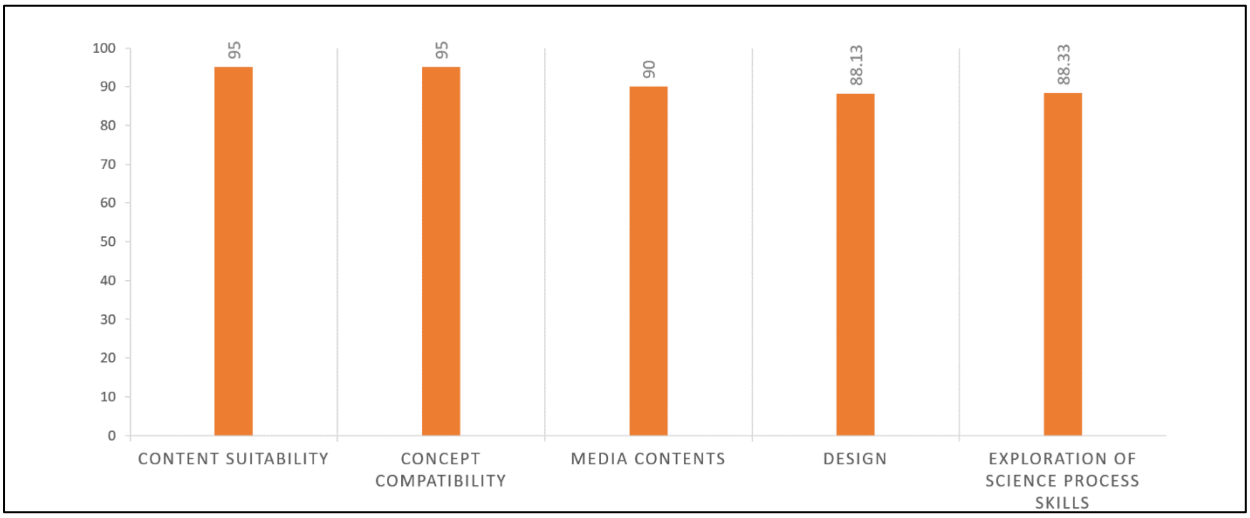


**Figure 11**. Validation Results of Experts (Teachers)

Based Figure 11, the five aspects of the assessment, namely content suitability, received score interpretation and concept suitability of 95%, media content of 90%, design of 88.12%, and science process skills of 88.33%. The average score interpretation range is in the range of 80-100% (very good).

Overall, the validation of the Wimhurst machine teaching aids by experts (teachers) received various suggestions and input to increase the use value of the teaching aid media, including:

1. The existing design is good, but replacing the aluminum foil used makes it easier
2. Safety in use still requires attention
3. The shape of the aluminum foil is replaced
4. To be added with interactive displays
5. The controller section can be opened/closed so that it can be used as a learning medium for other materials
6. Use of transformers made by students
7. There is still friction between the silk belts

Props are tested on students. After students observe the learning media, students are asked to fill out a questionnaire sheet. The students who took part in the Wimhurst machine demonstration test were 56 students from two high School.

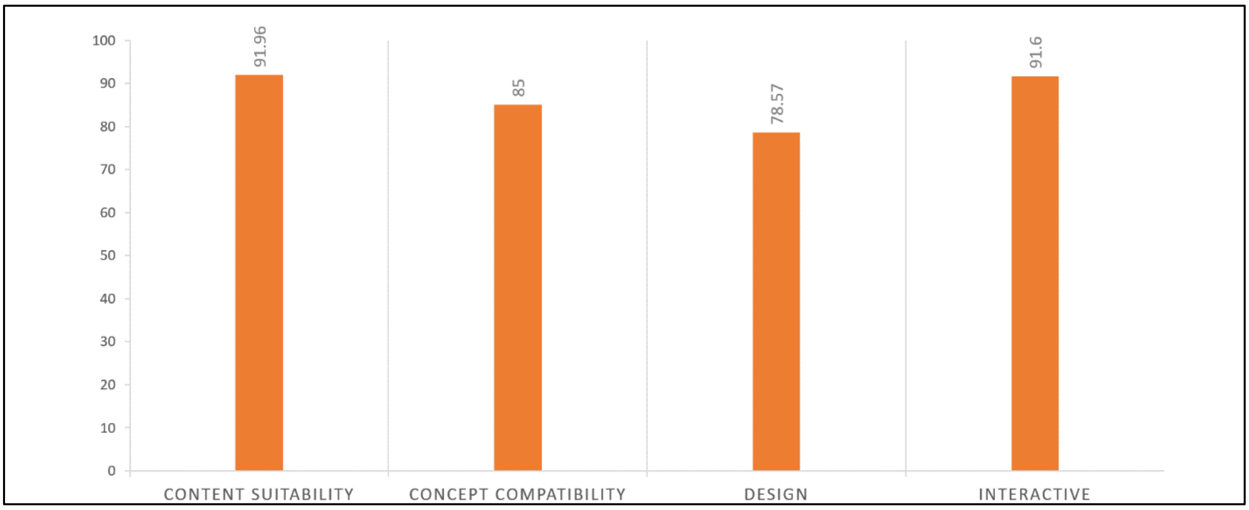


**Figure 12**. Validation Results of Student

Based on Figure 12, the four assessment aspects are content suitability of 91.96% (very good), concept suitability of 85% (very good), and instructiveness of 91.6% (very good). However, the interpretive design obtained a score of 78.57% (good), this was because students had difficulty assembling the media if they were not accompanied by a teacher.

## CONCLUSION

It was concluded that the development research that had been carried out had produced a Wimhurst machine trainer. The Wimhurst machine teaching aid can be used as a learning medium for Physics grade VIII middle school on the concept of static electricity. The Wimhurst machine demonstration tool can be used to explain the concept of electric charge jumps and static electricity phenomena in everyday life. The Wimhurst machine teaching aid is a learning medium that can be used by teachers as a demonstration tool that can help, simplify and clarify the delivery of learning material and messages. Apart from that, the Wimhurst machine teaching aid can make it easier for students to understand the learning material. With the development of the Wimhurst teaching aids, it is hoped that it can increase teacher creativity in developing learning media in the form of teaching aids.

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