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# Development of Scientific-Based Newton's Law Teaching Aids Using Arduino Uno Microcontroller

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**ABSTRACT**
*This research is intended to develop Newton's law teaching aids to understand Newton's law material in high school. In this study, validation process was carried out by three expert lecturers i.e. expert in the media field, expert in the material field, and expert in the pedagogic field. The data collection technique was carried out by providing a validation questionnaire in the form of a checklist. After that, the collected data were than analyzed using descriptive analysis by calculating the average of each indicator used to determine the validity of Newton's law teaching aids and the developed guidebook. The results of the study stated that the teaching aids and guidebooks on Newton's law materials developed were valid at a very satisfactory level. Therefore it can be concluded that Newton's law teaching aids have been successfully developed and can be used in the learning process.*

**Keywords**: *newton's law, teaching aids, arduino uno, microcontroller.*

## INTRODUCTION

Physics is a part of science that is very important in the development of science and technology (Novitasari et al., 2017). The learning process of learning physics is needed not only to study concepts or theories in the classroom, but requires supporting facilities such as the use of experimental tools in the laboratory (Yanti et al., 2017). Based on the results of the study by Subekti & Ariswan regarding learning physics using laboratory equipment facilities in experiments, it was found that the experimental method should be applied in the teaching process in schools (Subekti & Ariswan, 2016). The process of teaching and learning physics is often faced with an abstract material. This requires educators to create and develop learning media in order to make students can be more interested in studying physics and the material presented can be truly understood by students.

The four components that affect the success of student learning in the teaching and learning process are learning materials, learning environment, learning media, teaching aids and learning resources, and the teacher as the subject of education. If there are one or more problematic components, it can hinder the achievement of optimal learning goals. Research by Efriana states that one of the factors causing the lack of success in learning is due to the teacher's mistakes in choosing learning methods (Efriana, 2014). It often happens that the learning method used is not suitable for physics subjects. In addition, student learning success can also be influenced by the learning motivation of the students themselves. This is because based on

research results, it shows that student learning motivation actually has a major contribution to student achievement (Sulisworo & Suryani, 2014).

The use of various learning media in teaching and learning activities tends to be able to arouse students' motivation to participate actively in the learning process. One of the learning media that can be used in learning activities is visual aids. Physics teaching aids function to visualize something that students cannot or are difficult to see directly so that they can explain a main idea, working principle, indication, or natural law. In essence, visual aids can be defined as an alternative solution to students' problems (Demirbaş, 2014).

This is in accordance with research conducted by Indah regarding the development of visual aids to motivate students (Indah et al., 2018). Based on the results of this study, it was found that students were very enthusiastic when conducting experiments using visual aids. By using visual aids, students can be motivated to learn more about the material. This makes it easier for students to understand the concepts in physics material so that it can improve student learning outcomes in learning. One of the guidelines in supporting the development of knowledge, skills, basic needs for delivering material, concepts and physics information by educators is through the utilization of sensor-based experimental devices in the learning process in schools.

The teaching aids developed in this research are based on a microcontroller device, namely Arduino Uno as the main component. Arduino Uno is a small computer chip microcontroller using digital technology, used for a control system or controller and can be programmed as needed. The Arduino Uno microcontroller functions as a system controller which is then integrated with sensors (Rahayu & Fatmaryanti, 2020). Research conducted by Pambuka & Rahardjo found that physics practicum tools using sensors are believed to be more effective and efficient so that learning objectives can be carried out as expected (Pambuka & Rahardjo, 2018).

To be precise, the experimental tool developed is Newton's Second Law application teaching aid using a sensor connected to Arduino uno. Furthermore, the object is installed in the form of a sensor which causes more accuracy in taking time. The rope tension and friction coefficient can be seen on the LCD screen. To be concluded, this study has two main objectives, i.e. (1) to produce a product in the form of Newton's law teaching aids using the Arduino Uno microcontroller, and (2) to carry out the development of Newton's law teaching aids which can be used to improve conceptual understanding and students' learning motivation in Newton's Law.

## METHODOLOGY

This research is aimed at developing Newton's law teaching aids using the ADDIE model proposed by Dick and Carey (Sugiyono, 2014). The ADDIE Dick and Carry development model is one of the procedural models which suggests that the application of design principles or instructional design must be adjusted to the steps to be followed sequentially. The ADDIE model consists of several stages from analysis, design, development, implement, evaluate. At the analysis stage, a description of the potential and problems in learning is carried out. Then at the design stage, the design of Newton's law teaching aids is carried out using the Arduino Uno microcontroller and an experiment guidebook that suits your needs. The product design is produced in the form of hardware design and software design on Newton's law teaching aids while the guidebook is prepared according to the standards for preparing teaching materials set by (PDDikti Kemenristekdikti, 2017) in the "Guidelines for Preparing Teaching Materials". Then in the development stage an assessment is carried out on Newton's law teaching aids and guidebooks by experts based on input from experts.

This research is only intended to complete the development stage because the purpose of this research is to develop Newton's law teaching aids and valid guidebooks on high school Newton's laws material. The research was conducted at the Physics Education Laboratory, University of Riau. The time for conducting research is in the even semester of the 2021/2022 academic year. Apart from that, the types of data in this study are qualitative data and quantitative data. Qualitative data were obtained from suggestions for improvement during validation and validation results. Meanwhile, quantitative data is obtained from the assessment score by the validator. The instrument used was a validation sheet questionnaire in the form of media, material, and pedagogic aspects in the form of a checklist.

Moreover, in terms of data collection technique, this research used validation techniques by experts to measure the feasibility of the developed Newton's law teaching aids. The experts consist of 3 expert lecturers i.e. media expert lecturer, material expert lecturer, and pedagogic expert lecturer. In the first validation, the experts provided input for Newton's law teaching aids and guidebooks that were developed. Then in the next validation step, the experts assessed Newton's law teaching aids and guidebooks that had been developed in the form of a questionnaire in the form of a checklist. Data were analysed using descriptive analysis, namely by calculating the average of each indicator used to determine the validity of the teaching aids developed. The score is a number on a Likert scale with the highest score of 4 (strongly agree) and the lowest score of 1 (strongly disagree) (Sugiyono, 2014). The interpretation of the average validation score can be seen in Table 1.

**Table 1. Criteria Score Validation**

| No | Average Score | Category | Validity Value |
|---|---|---|---|
| 1 | >3,25 - 4 | Very High | Highly Valid |
| 2 | >2,5 - ≤ 3,25 | Height | Valid |
| 3 | > 1,75 - ≤ 2,5 | Low | Less Valid |
| 4 | 1 - ≤1,75 | Very Low | Invalid |

## RESULT AND DISCUSSION

In the analysis stage, problems were found through literature studies related to Newton's law teaching aids and environmental problems regarding the condition of experimental instruments in high school laboratories. In the current problem, it was found that the learning process has not fully used laboratory equipment in learning material. Therefore, the development of Newton's law teaching aids using the Arduino Uno microcontroller is very feasible to be carry out. One of the advantages of using Newton's law teaching aids is based on ultrasonic sensors in conducting experiments on Newton's law material. At this stage, the main material of the development of visual aids was also determined, namely Newton's second law.

After that, learning objectives were formulated in Newton's law material based on learning indicators. There are eight learning objectives, namely: (1) students can identify facts related to force; (2) students can explain the concept of force and motion of objects; (3) students can explain the forces acting on objects; (4) students can explain laws Newton about the motion of objects; (5) Students can describe the application of Newton's Laws; (6) Students can analyse the relationship between force, mass, velocity and acceleration in straight motion; (7) Students can conduct experiments on the interaction of forces and the relationship of force, mass, and acceleration in straight motion; (8) Students can present. Experimental results on the interaction of forces and the relationship between force, mass and acceleration in straight motion.

At the design stage, the design of Newton's law teaching aids and guidebooks has been determined. At this stage, the initial design of the teaching aids and guidebooks as experimental guides is carried out which contain covers, steps for props, preface, table of contents, general instructions for experiments, list of symbols, introduction to parts of Newton's law experimental

devices, general objectives of the experiment, basic theory, tools and materials, experimental instructions, and questions. The design of this props is as shown in Figure 1.

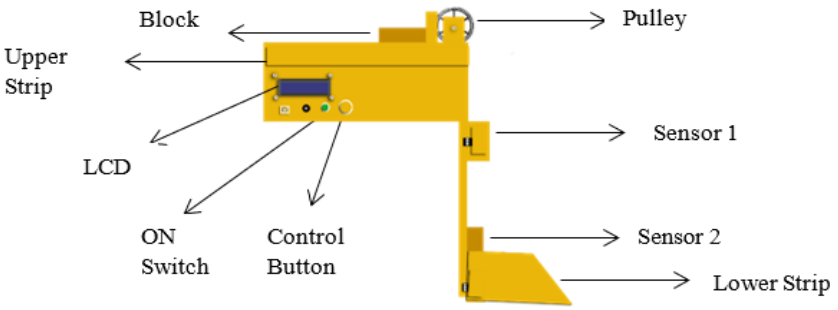



**Figure 1. Newton's Law Teaching Aid Framework.**

Figure 1 is a product design consisting of hardware and software designs. The process of making Newton's law teaching aids uses an ultrasonic sensor based on the Arduino Uno microcontroller. While the hardware design is a mechanical design and electronic design used in the development of Newton's law applications. The design of the software is Newton's second law where in certain parts an ultrasonic sensor is installed to see when an object starts to move until it falls to the bottom which is sent to the Arduino microcontroller. When the time is detected by the sensor, the value of the voltage and friction coefficient on rough and smooth surface objects is obtained which is displayed on the LCD. The design of the guidebook is based on the standards for preparing teaching materials set by the Ministry of Research, Technology and Higher Education. The references in compiling a guidebook are shown in Figure 2.


**Figure 2. Guidebook Design**

Based on the illustration in Figure 2, the design of this guidebook uses A5 sized paper (14.8 x 21 cm) with a tolerance of 5-20 mm, the thickness according to learning needs. This book is written using a semi-formal language style, the sentence structure follows the rules of EYD, SPOK (Indonesian) and is not plagiarism. In addition, the contents of this book do not deviate from the philosophy of the Unitary State of the Republic of Indonesia. In addition, the front cover of the book contains several components, namely the title, author's name, name of the institution, illustration and logo of the institution, while the back cover has the title, synopsis, and author's biography. The inside of the book consists of an introductory page, a table of contents, a list of tables, a list of pictures or graphics, a list of symbols or symbols and general instructions for carrying out the experiment (Sugiyono, 2015).

At the development stage, validation tests were carried out on Newton's law teaching aids and guidebooks by experts consisting of media validators, material validators, and pedagogic validators. Validation was carried out twice, in the first validation the validator gave suggestions

for revising Newton's law teaching aids. The suggestions from the validator for Newton's law props are: mark a different colour on each block as a marker of the mass of the block and the rough smooth surface of the block, the rail should be replaced with acrylic material, provide reinforcement to the pulley so it doesn't move. Once the first validation process completed, the second validation stage is carried out with the aim of providing an assessment by an expert validator. There are five aspects assessed in the media, namely, media design, content feasibility, convenience feasibility, durability feasibility, device function. While in the material assessment there are three aspects, namely, the learning aspect, the feasibility of presentation, the feasibility of the content. Then in the pedagogic assessment there are two aspects, namely, pedagogic principles, the Arduino Uno microcontroller. Data from the validation results of Newton's law teaching aids that have been assessed by experts can be seen in Table 2 as follows.

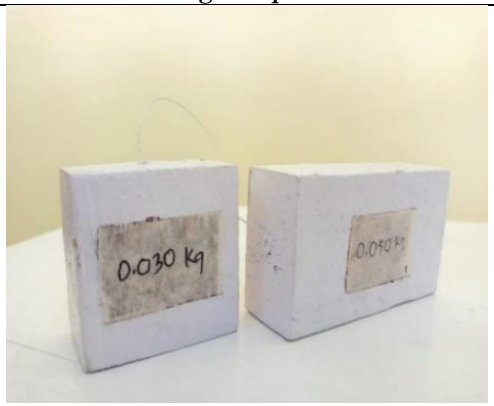
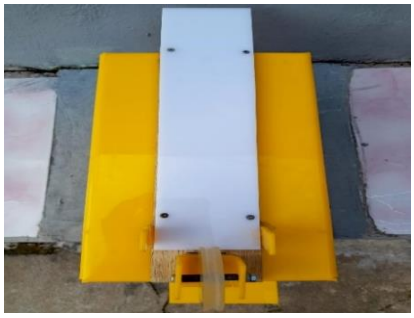
**Table 2. Results of Newton's Law Teaching Aids Validation**

| No | Aspect | Expert | | | Average |
|---|---|---|---|---|---|
| | | V1 | V2 | V3 | |
| 1 | Media Design | 3,40 | 3,80 | 3,40 | 3,53 |
| 2 | Content Eligibility Aspects | 3,25 | 3,50 | 3,00 | 3,25 |
| 3 | Facility Feasibility Aspects | 3,33 | 3,66 | 3,66 | 3,55 |
| 4 | Endurance Feasibility Aspect | 3,50 | 4,00 | 4,00 | 3,83 |
| 5 | Aspects of Device Functions | 3,50 | 3,50 | 4,00 | 3,66 |
| Average Rating of Each Aspect | | | | | 3,56 |

Table 2 contains several assessment aspects of Newton's law teaching aids, such as aspects of media design, content feasibility, convenience, robustness, and device functions. Overall, the average aspect rating is 3.56. This indicates that the Newton's law teaching aids have met the assessment criteria contained in the validation sheet and the Newton's law teaching aids using the Arduino Uno Microcontroller can be declared valid, and the results of the teaching aids validation show that each validation assessment item obtains an average score of ≥ 3, 00. There are several responses, criticisms and suggestions from the validator that researchers must pay attention to. The detailed responses, criticisms and suggestions provided by the validator can be presented in Table 3.

**Table 3. Responses, Criticism, and Suggestions for Newton's Law Teaching Aids.**

| No | Feedback, Criticism, and Suggestions | Image Props |
|---|---|---|
| 1 | The appearance of the beam is better painted to make it more attractive. | Before<br>  <br>After |

| No | Feedback, Criticism, and Suggestions | Image Props |
|---|---|---|
| | |   |
| 2 | The rail track is better given attractive colors and acrylic materials. | Before  After  |

The revision of Newton's law teaching aids in Table 3 was carried out based on the responses, criticisms and suggestions from the validators. This is carried out in order to make the quality of Newton's law teaching aids even better. Thus, Newton's law teaching aids are easy to use and understand the correct concepts. The results of assessing the validity of the material on Newton's law teaching aids were carried out by the material expert validator, which can be shown in Table 4.

**Table 4. Results of the Validity Test of Newton's Law Teaching Aid Material.**

| No | Aspect | Expert | | | Average |
|---|---|---|---|---|---|
| | | V1 | V2 | V3 | |
| 1 | Learning Aspects | 3,60 | 3,80 | 3,20 | 3,53 |
| 2 | Presentation Feasibility Aspects | 3,66 | 3,50 | 4,00 | 3,72 |
| 3 | Content Eligibility Aspects | 4,00 | 4,00 | 3,00 | 3,66 |
| | Average Rating of Each Aspect | | | | 3,63 |

Table 4 contains several assessment aspects of Newton's law teaching aids i.e. learning aspects, presentation feasibility, and content feasibility consisting of 13 validation assessment points. Based on the table, it is known that the average validation item gets an average score ≥

3.00. Overall, the average rating is 3.63. This indicates that the learning media for Newton's law visual aids have met the assessment criteria found on the validation sheet and are declared valid. Assessment of pedagogic validity is an assessment carried out to see that Newton's law teaching aids contain pedagogic elements. The results of the Pedagogic Validity Assessment from the pedagogic expert validator are shown in Table 5.

**Table 5. Results of the Pedagogic Validity Test of Newton's Law Teaching Aids.**

| No | Aspect | Expert | | | Average |
|---|---|---|---|---|---|
| | | V1 | V2 | V3 | |
| 1 | Pedagogic Principles | 3,66 | 3,66 | 3,66 | 3,66 |
| 2 | Arduino Uno microcontroller | 3,33 | 3,66 | 3,00 | 3,33 |
| Average Rating of Each Aspect | | | | | 3,49 |

Based on Table 5, it can be seen that there are several aspects of the assessment of Newton's law teaching aids, namely the pedagogic principles of developing Newton's law teaching aids and the pedagogic substance of the components of Newton's law teaching aids using the Arduino Uno Microcontroller. Apart from that, from the 2 existing assessment aspects, there are 9 validation assessment points. In addition, based on the table it is also known that the average validation item gets an average score ≥ 3.00. Overall, the average aspect rating is 3.49. This indicates that the learning media for Newton's law visual aids have met the assessment criteria found on the validation sheet and are declared valid.

Newton's law visual aids learning media that have been developed are tested to obtain physics learning media that are feasible (valid) and practical and effective for use in learning. The results of the expert validation test on Newton's law teaching aids as a whole were declared very feasible with a score of 3.56. So it can be concluded that Newton's law visual aids are easy to use. As stated by Tuncel, the purpose of learning media is as a tool that helps in the learning process in the classroom (Tuncel & Bahtiyar, 2015).

The validation test is then carried out on the manual by the user to conduct experiments on Newton's law material. Manual book validation was carried out twice, the first validation expert validator gave suggestions for revising Newton's law teaching aids. As for suggestions for improvements to the guidebook, it is sufficient to write down the author's biodata briefly, each activity sheet does not need to write down the name of the user group, and use observation tables and graphs for experimental data.

After the guidebook is validated, a second assessment is given by an expert validator. There are six aspects assessed in the media, namely guidebook design, guidebook aspects, content feasibility aspects, procedural aspects, questions aspects, and graphical feasibility aspects. While in the assessment of the material there are three aspects, namely, the feasibility aspect of the content, the feasibility aspect of presentation, the learning aspect. Then in the pedagogic assessment there are four aspects, namely, scientific approach learning, guidebook competency components, the ability to respond to learning, and language feasibility.

The teaching aids manual that has been designed and made is then assessed by the validator. The media expert's validity assessment of the guidebook is carried out by assessing the feasibility of the guide in using visual aids. The results of the validation assessment of Newton's law teaching aids guidebook can be seen in Table 6.

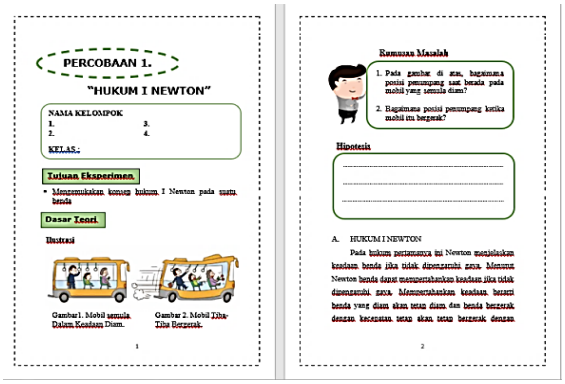
**Table 6. Results of the Handbook Media Validity Test.**

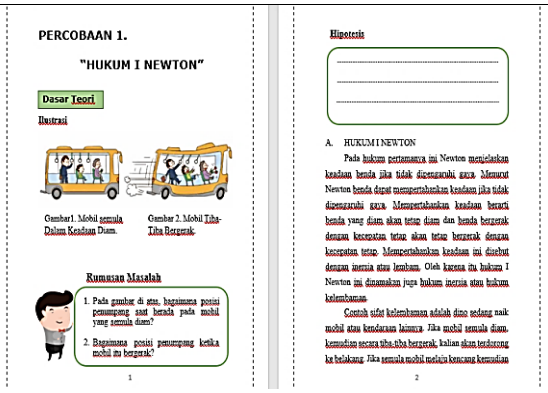
| **No** | **Aspect** | **Expert** | | | **Average** |
|---|---|---|---|---|---|
| | | **V1** | **V2** | **V3** | |
| 1 | Guidebook Design | 3,25 | 4,00 | 3,75 | 3,66 |
| 2 | Aspects of Guidance | 3,33 | 3,66 | 3,33 | 3,44 |
| 3 | Content Eligibility Aspects | 3,50 | 3,50 | 3,33 | 3,44 |
| 4 | Procedure Aspect | 3,50 | 3,00 | 4,00 | 3,50 |

| No | Aspect | Expert | | | Average |
|---|---|---|---|---|---|
| | | V1 | V2 | V3 | |
| 5 | Question Aspect | 3,33 | 3,33 | 4,00 | 3,55 |
| 6 | Graphical Feasibility Aspects | 3,25 | 3,75 | 3,75 | 3,58 |
| | Average Rating of Each Aspect | | | | 3,52 |

Based on Table 6, there are several aspects of the evaluation of the guidebook such as aspects of the design of the guidebook, aspects of the guidebook, content feasibility, procedures, questions, and graphic feasibility. Overall, the average rating for each aspect is 3.52. This indicates that the manual for Newton's law teaching aids has met the assessment criteria contained in the validation sheet and can be a guide for users of Newton's law teaching aids which are declared valid. There are several responses, criticisms and suggestions from the validator that researchers must pay attention to. Responses, criticisms, and suggestions provided by the validator in detail can be presented in Table 7.

**Table 7. Responses, Criticisms, and Guidebook Suggestions.**

| No | Feedback, Criticism, and Suggestions | Guidebook Image |
|---|---|---|
| 1 | The back cover of the guidebook for the display of the large logo is removed, just one institutional logo on the front cover of the guidebook | Before   After   |
| 2 | Fix for the column name group and class identity no longer need to be written because this manual is used by users in general and the purpose of the experiment is made as a whole just the front of the experimental activity. | Before   After |

| No | Feedback, Criticism, and Suggestions | Guidebook Image |
|---|---|---|
| | |  |



The revision of the guidebook in Table 7 was carried out based on the responses, criticisms and suggestions from the validators. This is performed hence the guidebook can be used by teachers and students as well as other general users. The guidebook is made more attractive in colour display and the language used is easy to understand. There is a revision given by the validator's suggestion that the institutional logo is better only displayed on the front cover of the guidebook. As for the group name column on the experimental activity sheet, there is no need to make it because the guidebook is useful for the public, especially teachers and students. The results of assessing the validity of the material in the guidebook were carried out by the material expert validator, which can be shown in Table 8.

**Table 8. Results of the Guidebook Material Validity Test.**

| No | Aspect | Expert | | | Average |
|---|---|---|---|---|---|
| | | V1 | V2 | V3 | |
| 1 | Content Eligibility Aspects | 3,77 | 4,00 | 3,44 | 3,73 |
| 2 | Presentation Feasibility Aspects | 3,75 | 4,00 | 3,62 | 3,79 |
| 3 | Learning Aspects | 3,75 | 4,00 | 3,75 | 3,83 |
| Average Rating of Each Aspect | | | | | 3,78 |

Table 8 contains several aspects of the assessment in the guidebook, namely aspects of content feasibility, presentation feasibility, and learning which consists of 21 validation assessment points. Based on the table it is known that the average of each validation item gets an average score ≥ 3.00. Overall, the average rating is 3.78. This indicates that the guidebook has met the assessment criteria and is suitable for use as a guide in conducting Newton's law props experiments. Assessment of pedagogic validity is an assessment carried out to see if the guidebook contains pedagogic elements. Results of the Assessment the pedagogic validity of the guidebook was assessed by the pedagogic expert validator shown in Table 9.

**Table 9. Results of the Guidebook's Pedagogic Validity Test.**

| No | Aspect | Expert | | | Average |
|---|---|---|---|---|---|
| | | V1 | V2 | V3 | |
| 1 | Scientific Approach Learning | 3,50 | 3,50 | 3,00 | 3,33 |
| 2 | Guidebook Competency Components | 3,75 | 4,00 | 3,75 | 3,83 |
| 3 | Ability to Respond to Learning | 3,50 | 3,75 | 3,00 | 3,41 |
| 4 | Language Eligibility | 3,50 | 3,50 | 3,00 | 3,33 |
| Average Rating of Each Aspect | | | | | 3,47 |

Table 9 contains several aspects of the assessment in the guidebook, namely learning aspects based on a scientific approach, the competency components of the guidebook, the ability

to respond to learning, and language feasibility which consists of 14 validation assessment points. Based on the table it is also known that the average validation item gets an average score ≥ 3.00. Overall, the average aspect rating is 3.47. This indicates that the guidebook has met the assessment criteria contained in the validation sheet and can be declared valid and suitable to be used.

Based on the results of research conducted by Hapsoro and Susanto, it was found that teaching aided learning can achieve students' basic competencies and improve learning outcomes. In addition, teaching aids assisted learning is better than conventional learning as indicated by the increase in students' cognitive learning outcomes (Hapsoro & Susanto, 2011). The results of other studies that agree are stated by Setiawardhana. This study stated that the use of visual aids in learning physics increases learning outcomes, creativity and student activity in learning physics (Setiawardhana, 2016).

Hence, it can be concluded that the presence of learning media in the form of visual aids is very important for the physics learning process because learning using visual aids can help students more easily understand the concepts being studied. Based on these conditions, learning media is needed to assist the teaching and learning process in the classroom. Students need to be given observing and experimenting activities so that students have direct experience in learning. Students are happy and can interact with fellow group members in learning (Sobari & Sucahyo, 2016). By using teaching aids, students are motivated to learn more about the material.

Furthermore, Experts, teachers, and students state that learning media for Newton's law visual aids using the Arduino Uno Microcontroller is a feasible, practical and effective medium for learning physics. The learning media consists of teaching aids for Newton's law using the Arduino Uno Microcontroller and props guidebooks. In accordance with the statement from Alatas and Astuti that teaching aids are needed by students so that they can better understand the concepts learned in physics learning and are more effective and efficient in using practicum time (Alatas & Widia, 2019).

## CONCLUSION

Based on the research that has been done, it can be concluded that Newton's law teaching aids using the Arduino Uno microcontroller and a guidebook as a guide for Newton's law experiments on Newton's law material have been successfully developed to obtain valid criteria, based on the average score of validation results from experts. The valid criteria for Newton's law teaching aids and guidebooks are found in the valid category. Therefore, Newton's law teaching aids can be used in Newton's law experiments in the learning process to support learning activities to be better and easier to understand the material.

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