ISSN (Print) : 2337-9030 ISSN (Online) : 2685-2608
PILLAR OF PHYSICS
JURNAL BERKALA ILMIAH FISIKA
Vol. 16 (2), 2023, page. 109-122
DOI : 10.24036/15044171074

DEVELOPMENT OF CONNECTED WHEEL MOTION EXPERIMENT SYSTEM WITH REMOTE LABORATORY BASED IOT USING THE WEB

Rahmat Dito Tri Wicaksono, Asrizal*, Yohandri, Hufri, Rio Anshari

Department of Physics, Universitas Negeri Padang, Jl. Prof. Dr. Hamka Air Tawar Padang 25131, Indonesia

Corresponding author. Email: asrizal@fmipa.unp.ac.id

ABSTRACT

Remote measurement is a trend that is in great demand today. The development of connected wheel motion experiment system with a remote laboratory is aimed at effectiveness in experimental activities. This research is based on the weaknesses of previous research that there is no login system, queuing system, and time limit for using the experimental system. Based on these weaknesses, this study provides a solution to the experimental system with a login system, queuing system, and time limit for using the device. The Design and Development (D&D) method is the method chosen in this study. From the data analysis it can be stated in general that there are two results in this study. The first result is the performance specification of the related wheel drive experimental system where the function of each component of the experimental system has a performance according to the function of each component. The second result is the accuracy and precision of the associated wheel motion experimental system. Accuracy results for concentric wheels, obtained an average accuracy of 97.19% and 98.23%. Accuracy for connected wheels to ropes obtained an average result of 98.28% and 98.98%. The results of the angular velocity precision test on concentric wheels obtained an average of 99.43% and 99.09%. The precision of the angular velocity obtained on the wheels connected by a rope is 99.68% and 97.78%

Keywords : Remote Laboratory; Experiment; Connected Whell Motion; Web

I. INTRODUCTION

Currently education is in the knowledge age with an extraordinary acceleration of knowledge increase. This accelerated increase in knowledge is supported by the application of digital media and technology called the information super highway [1]. The style of learning activities during the knowledge age must be adapted to the needs of the knowledge age. One of the technologies that is developing at this time is technology in measurement. Remote measurement is a popular trend today. In remote measurements, you can use a variety of instruments, one of which is popular, namely IoT-based.

Remote measurements in experiments can be a solution to various problems. Experiments in the laboratory are generally carried out manually. The experiment can be done if the user is in the laboratory. If the user is unable to go to the laboratory, the user must find a replacement schedule to carry out experimental activities. In this study, remote measurements were carried out using a remote laboratory[2]. Based on these limitations, remote laboratory or remote measurement in experiments is the answer because it can be done anytime and anywhere.

Experiments play an important role in science [3]. The experiment aims to make researchers able to find and find various answers or problems themselves by conducting their own experiments so that researchers are trained to think scientifically. Physics experiment is a research methodology that is often used to find out whether there is an effect of treatment on controlled conditions [4]. The purpose of the experimental activity is the ability to seek and find answers to the problems faced. This experimental activity makes it easier to understand the answers to the problems faced because the experimental activities are done alone. Experimental activities will produce new insights based on new observations[5]. The experimental set is a teaching tool that has the goal of effective learning[6]. The requirements of the experimental tool are in accordance with the concepts of physics and easy to understand and easy to use.

The use of an experimental system of connected wheel drive devices will help the effectiveness of the learning process as well as the delivery of messages and lesson content. In addition, the experimental tool will also provide a visualization of the actual concept. The development of a related wheel motion experiment system is based on the shortcomings and weaknesses of previous studies. Previous researchers who did research on the development of experimental wheel modeling related to control progress using video tracker analysis had also made experimental activities by utilizing virtual media [7]. The limitation in this study is that it cannot be done remotely or remote laboratory practicum so that you have to use the tool directly. Another research entitled design of connected wheel motion experimental system to remote laboratory using blynk software. Researchers investigate the connected wheel motion that is controlled remotely using blynk software. This study has limitations, namely there is no login system and queuing system so that practicum practitioners do not have a time limit for using practicum tools[8].

In real conditions these solutions are felt to be insufficient and less effective. In experimental science learning is needed in proving the theory. Misunderstanding will occur if the understanding of the theory is low, especially in relation to wheel motion[9]. Based on these limitations and deficiencies, the basis for this research is the development of connected wheel motion experiment system with remote laboratory using the web. The experimental system developed is expected to display reading data on the web. In the experimental system there is a login system to control the experimental set, a queuing system on the web and usage time restrictions. These characteristics will be an added value in the development of an experimental wheel drive system so that its use will be more practical, effective and efficient. Based on this solution, there is no longer any struggle over the use of the experimental system by practitioners because it has already been determined who and when to use the experimental system.

Uniform circular motion is the motion of an object that travels in a circular path with a constant speed, but its direction is always changing, and the direction of velocity is always tangent to the circle. So, the direction of velocity (v) is always perpendicular to the line drawn through the center of the circle to the point of capture of the velocity vector at that time [10]. The relationship of the wheels in uniform motion occurs due to the existence of linear speed and angular speed [11]. The linear velocity (v) is the quotient of the length of the linear path traveled by the object by the time interval it has traveled. Meanwhile, the angular velocity (ω) is the angular magnitude traveled per one unit of time[12]. The relationship between the wheels in circular motion can be a direct system, namely by using gears or friction wheels, or an indirect system, namely by using a rope.

The movement of connected wheels is an interesting event to study. Connected wheel motion plays an important role in everyday life, for example we can find it on motorbikes where the front and rear gears are connected by a chain. In other cases, related wheel motion can be found in compressors, rice milling machines and many more. Connected wheel motion is divided into 3 types of motion, namely motion with a rope, unidirectional motion, and tangential motion. The phenomenon of connected wheel moving objects can be proven with an experiment.

Wheels connected by a rope are two wheels that are spaced apart but connected by a rope or the like and have the same direction of rotation. The relationship of the wheels connected by a rope can be seen in the Figure 1.

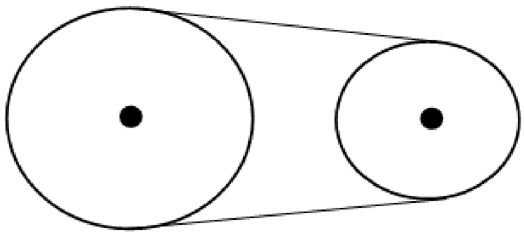

Fig. 1. Wheel movement with a rope

From the notion of linear velocity, the direction of linear velocity is always tangent to the circle. The chain or rope used to connect the rear and front wheels are attached to the outside of each wheel. When moving, the velocity of the wheel or rope touches the outside of the wheel. So it can be concluded that the direction and magnitude of the linear (tangential) velocity on the two wheels connected by a rope are the same (equation 1).

$$v_1 = v_2$$

$$\omega_1 . R_1 = \omega_2 . R_2 \qquad (1)$$

Concentric wheels are two wheels that have the same center point, points A and B each located on wheels 1 and 2 are said to be concentric. The relationship of the concentric wheels can be seen in the Figure 2.

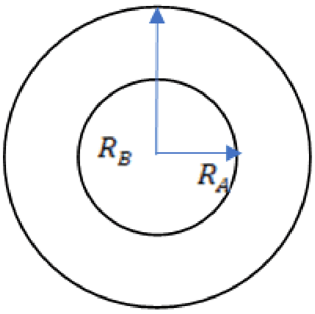

Fig. 2. Central wheel movement

Even though the two wheels are in the same center, they have different sizes. So are their fingers. The radius of wheel A will be smaller than that of wheel B. In a concentric wheel relationship, the angular velocity of the big wheel and the small wheel will always be the same. but the linear speed is different. In this case, we can look at equation 2.

$$\omega_A = \omega_B$$

$$\frac{v_A}{R_A} = \frac{v_B}{R_B} \qquad (2)$$

If the two wheels are rotated counterclockwise, in the time interval , points A and B will arrive at points A' and B' [13]. The angle taken by each wheel in the same time is the same, namely θ in that time interval[14]. To connect the experimental system to the internet, researchers use the Internet of Things (IoT). Internet of things (IoT) methodology communicates both humans and devices electronically concerning control modules[15]. The Internet of Things (IoT) can connect everyday things like smartphones, laptops, internet TVs, sensors and actuators to the internet where devices are linked together enabling new forms of communication between those things and people, and between things it self [16]. Experiments use real components or instrumentation in different locations from where they are controlled[17]. Remote laboratories have certain advantages compared to virtual laboratories because with remote laboratories students can carry out practicum activities with flexible time, students can carry out practicums without having to go to the laboratory, increase the effectiveness of time spent in the laboratory with practice, and increase safety and security because there is no there is a risk of failure caused by physical contact during experiments in remote laboratories. Users can interact directly with laboratory equipment when users run programs and programs can be observed in laboratories through cameras installed in the system [18].

Remote measurement requires several components in its application. NodeMCU in this study acts as a connecting tool with the internet. NodeMCU is a website that uses a programming language to produce IoT. The use of NodeMCU ESP 8226 is commonly used for IoT applications. Along with the development of technology that is all practical and online, there is a lot of research in android-based control by utilizing the Internet Of Things (IoT) system[15]. This NodeMCU is a WIFI module. In controlling this NodeMCU receives input from a sensor in the form of a webserver that is on NodeMCU. Data will be sent via WIFI if there is data read by NodeMCU. This enables remote use of NodeMCU [19].

In general, the web is an information page that is provided via the internet so that it can be accessed throughout the world as long as it is connected to the internet network. The website is computer network-based information that can be accessed anywhere [20]. Web applications have now become an inseparable part of everyday life, because to obtain information in current circumstances everything is obtained through web-based applications and mobile applications. This of course makes it easier for human activities to get information from the use of this web application. However, nothing is perfect in this world, the various advantages of web applications in the internet world also have weaknesses related to security aspects, which are very vulnerable to attacks from irresponsible parties [21].

Experimental activities can be carried out in any learning activity. Experimental activities can be replaced by using virtual experiment media on a computer as an alternative to real experiments. Learning physics by utilizing videos of physics incidents allows researchers or students to explore physics concepts through analytical activities. Previous researchers used tracker software to assist in analyzing a movement that is difficult to observe directly [7].Virtual laboratory is an excellent teaching aid for understanding some phenomena, however, experimentation with actual instrumentation is irreplaceable. despite the possibility of complex experimental models to be developed. In fact, direct experience can only be experienced through an actual laboratory session.

The associated wheel motion experiment using a remote laboratory has other advantages and conveniences. By using a remote laboratory, researchers can access practicum activities anytime and anywhere, as long as their smartphone/PC is connected to a Wifi network. Movement of practicum activities, and practicum results data can be seen by students from the Smartphone/PC used. Students use the Web on a smartphone/PC which will be used as a sender of input between the microcontroller and smartphone/PC. Therefore, the researcher is interested in raising the research title on development of connected wheel motion experiment system with remote laboratory bases IoT using the web.

II. METHOD

This research method belongs to the type of design and development research or design and development research (D&D). Based on the opinion of Richey and Klein [22] that the D&D model is a systematic study of the design, development and evaluation process with the aim of establishing an empirical basis in the creation of instructional and non-instructional products and tools as well as new or enhanced models. This type of design and development research presents the potential to make a meaningful contribution, the problem must be one that can actually be solved by some form of creativity or human interaction. Design and development research will not be appropriate if the development of some form of product does not show the potential to overcome the problem [23]. This research method has six stages of research procedures, the six procedures are (1) identifying problems, (2) describing objectives, (3) designing and developing systems, (4) system testing, (5) evaluating test results, (6) communicating test results. The research carried out must be based on the steps that have been mentioned so that the research process can run properly according to the actual procedure.

In the stages of designing and developing the tools of the hooked drive system, it consists of: block diagram design for the hooked drive system, display design on the web, and mechanical design for the hooked drive system. The first step is to design a block diagram of the linked wheel drive system shown in Figure 3.

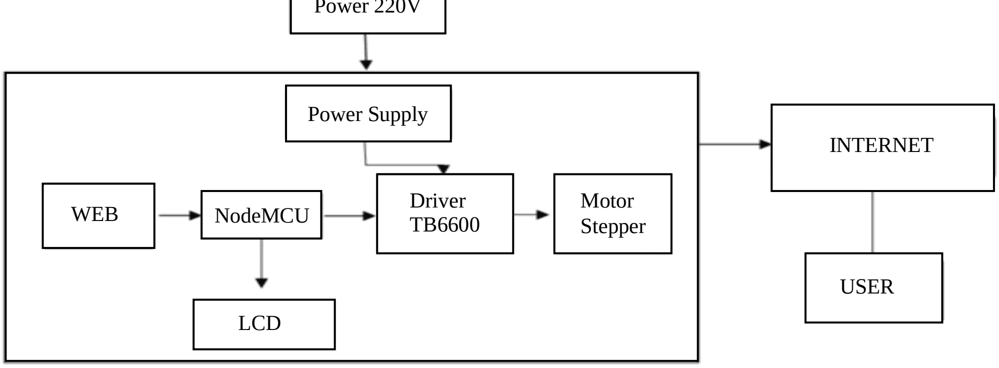

Fig. 3. Block diagram design of connected wheel motion system

From figure 3, it can be analyzed that the Web is a place for inputting data, which will be programmed using NodeMCU, NodeMCU is also useful as a connection to the experimental system with the internet, so that data input using the internet network can be read. The power supply functions as a supply of electric current to components, the TB660 driver functions as a controller for the stepper motor motion, and the stepper motor functions as a drive for the wheels used, after the wheels move the data will be displayed on the LCD. The display will show the wheel velocity (rpm), and the number of turns. The second stage is to make the display design on this website shown in Figure 4.

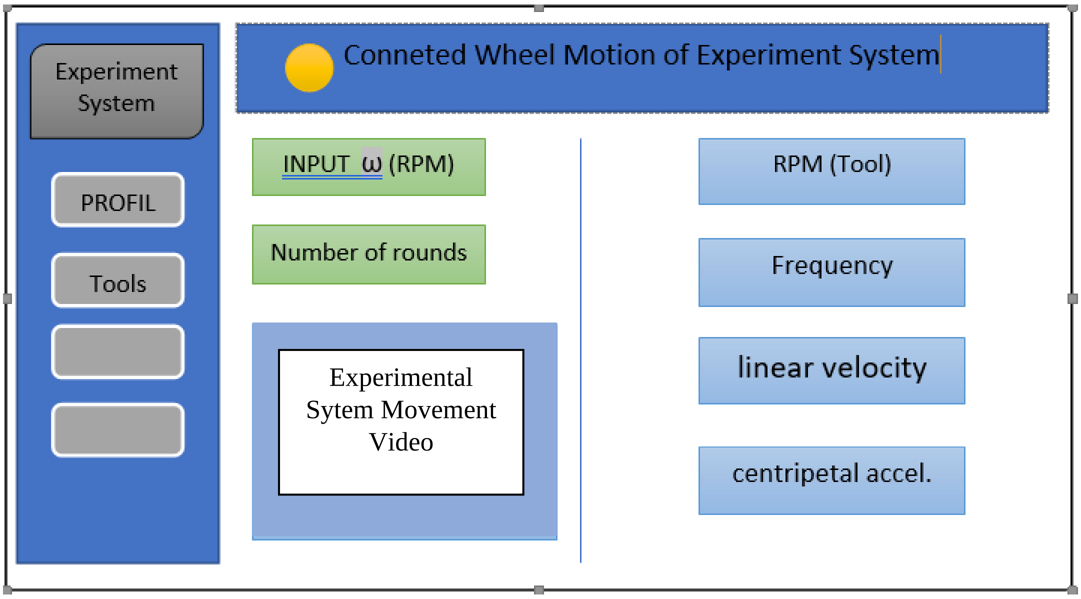

Fig. 4. Web display design on connected wheel motion system

In figure 5 the web display design will display angular velocity, linear velocity, and other physical quantities on each wheel that has been read by the tool. The display on this website also shows a video of the tool moving after the angular velocity data has been entered. The final or fourth stage in designing and developing tools is the mechanical design of the linked wheel drive system shown in Figure 5.

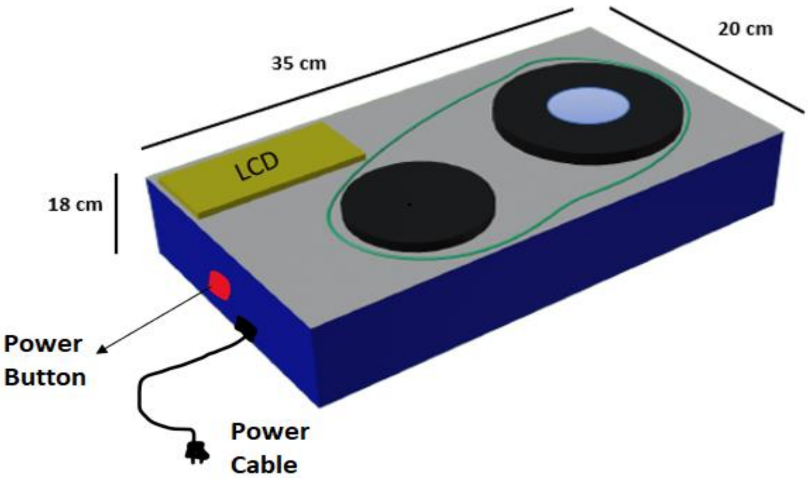

Fig. 5. Mechanical design of connected wheel motion system

Based on Figure 6, the manufacture of wheel drive devices is related to using a stapper motor as a motor drive. The TB6600 driver controls the motion of the motor, and the power supply functions as a supply of electric current to the components. This design is designed with two wheels attached to the center and one of the wheels is connected by a rope with the other wheel. The tool that is designed to be connected to the internet network requires NodeMCU to be useful for making prototypes of IOT (Internet of Things) products. Speed input points, and many spins on the wheel using the Web.

III. RESULTS AND DISCUSSION

The connected wheel motion experiment system with remote laboratory for remote measurements consisting of electronic circuits. The electronic circuit in the wheel motion experiment system is related to this remote laboratory so that the performance of the system can work properly and according to needs. The electronic circuit which is the main circuit of the wheel motion experiment system related to the remote laboratory consists of several components. The assembled frame is packaged in a rectangular box. The results of the wheel motion modeling tool related to the remote laboratory can be seen in Figure 7.

Fig. 7. Connected wheel motion modeling tool

In Figure 7 it can be described that the wheel motion model tool is connected which consists of 3 spokes of the wheel and 2 types of motion, namely centralized wheel motion, and wheel motion with a rope. Each wheel has a diameter of 13.1 cm, 8.6 cm and 8.6 cm. In the related wheel drive model tool set, a blue and white acrylic box is used as a place to place the wheels measuring 35 cm long, 20 cm wide, and 18 cm high. The wheels are made of black disc-shaped acrylic.

The research data were obtained directly from the experimental set of circular motion on the associated wheel. The data obtained is expressed in tabular form. The data can be obtained from measurements and calculations using the formula for the quantities present in circular circular motion. On the other hand, to determine the accuracy and precision of the connected wheel motion experimental system with this remote laboratory, data analysis is required. This study has two general results, namely the performance test results of each component of the connected wheel motion experimental system and the results of the precision and accuracy test of the connected wheel motion experimental system.

Performance specifications are specifications related to the performance of a device. The work of a tool is related to the basic operating characteristics of the tool. The basic operations of the wheel motion modeling tool related to the remote control consist of: stepper motor capability to control angular speed, electronic circuit capability to display data, remote control capability to control wheel movement, and Web view capability to display tool reading data.

The stepper motor rotation performance depends on the TB6600 driver. The stepper motor functions as a disk drive. The stepper motor will rotate according to the value of the input angular velocity. Stepper motor moves with TB600 driver control. The stepper motor will move according to the digital pulses and not from the continuously applied voltage. In this study, 9 data were taken from the angular velocity of 45 rpm to 105 rpm. The performance of stepper motors and drivers TB-6600 can work well can be described from the measurements in Table 1.

Table 1. Angular Velocity Measurement Based on Stepper Motor and Driver TB-6600

NO	ω input (RPM)	ω Tool (RPM)	Accuration (%)
1	45	46.27	97.18
2	55	55.45	99.18
3	65	66.32	97.97
4	75	76.29	98.28
5	85	84.75	99.71
6	95	96.04	98.91
7	105	105.86	99.18
8	115	114.35	99.43
9	125	124.12	99.30
Average			**98.79**

Based on table 1 it can be explained that the stepper motor is working well, this is evidenced by the results of reading the motor speed on the device where the stepper motor will move the disc. This disc will be a demonstration of the associated wheel motion. The results of this test take data as much as 9 pieces of test data. From the results obtained, it can be concluded that the accuracy of the results of this test has a percentage of 98.79%. The highest accuracy is found at 115 rpm and 114.35 rpm readings with an accuracy of 99.43%. the lowest accuracy is found at 45 rpm speed and 46.27 rpm tool reading results with 97.18% accuracy. the difference between the highest and lowest accuracy in the stepper motor performance test results is 2.25%. From the data shown in table 1 it can be seen that the angular velocity value at the input is not much different from the angular velocity measurement data on the tool.

The performance measurement of NodeMCU and this LCD depends on the readings of the tools conveyed by the NodeMCU output displayed on the LCD which is based on the results of reading the stepper motor rotation. The results of this speed measurement are obtained from the reading of the sensor on the disk in the form of a period which is then processed in the program embedded in NodeMCU, so that the speed measurement results are obtained as displayed on the LCD. To test the performance of NodeMCU, angular velocity measurements were carried out in the range of 40-120 RPM, which can be seen in Table 2.

Table 2. NodeMCU Performance on Angular Velocity Measurement

NO	ω input (RPM)	ω tool (RPM)	Accuration (%)
1	45	46.27	97.18
2	55	55.45	99.18
3	65	66.32	97.97
4	75	76.29	98.28
5	85	84.75	99.71
Average			**98.46**

In table 2 it can be concluded that the performance of the stepper motor with a display on the LCD is said to work well. Based on the data obtained, it is not much different from the value entered with the value obtained on the LCD. From the results obtained, it can be described that the accuracy of the LCD test results has a percentage of 98.46%. The highest accuracy is found at the speed of 85 rpm and the results of reading the instrument at 84.75 rpm with an accuracy of 99.71%. the lowest accuracy is found at 45 rpm speed and 46.27 rpm tool reading results with 97.18% accuracy. the difference between the highest and lowest accuracy in the stepper motor performance test results is 2.25%. This reading proves that nodeMCU's performance with this LCD is running as it should.

The display on the PC/smartphone display is in the form of input and output which is accessed via a web page. On the PC/smartphone display, the input is shown in the form of angular velocity and the number of revolutions while the output is in the form of frequency, period, angular velocity, linear speed and centripetal acceleration. For the display on a PC, it can be seen in Figure 8.

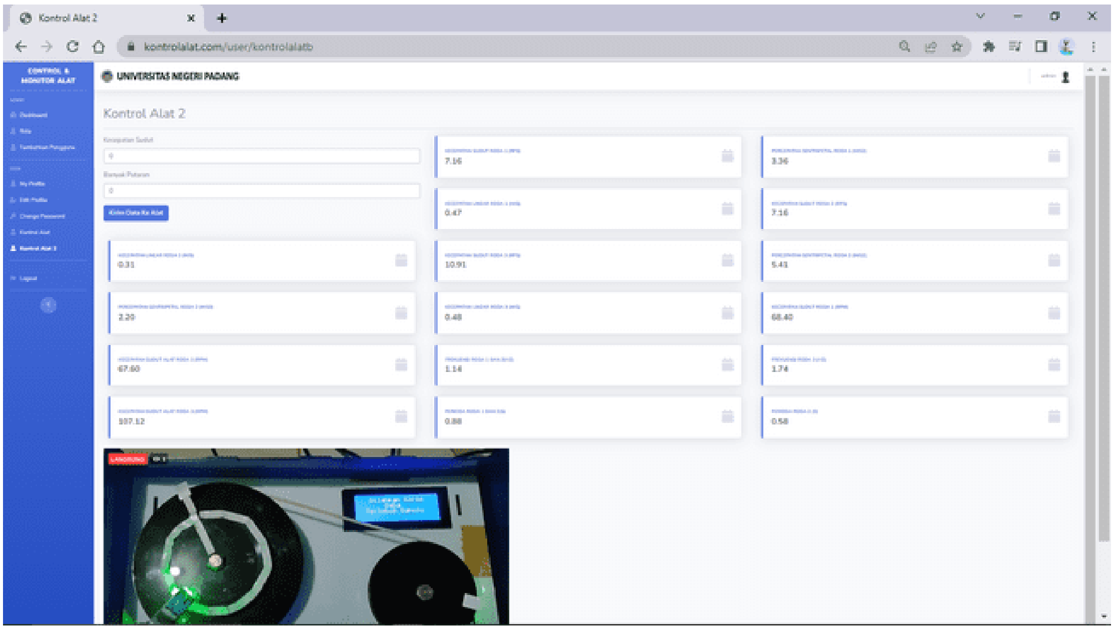

Fig. 8. Web display performance test results.

In figure 8 it can be explained that the display on the laptop display will be as shown in the picture. The displayed output is the result of counting and reading on the associated wheel motion experimental tool set. In the picture there is an output display of angular velocity, frequency, period, linear speed on each wheel.

Specifications include the results of the precision and accuracy of the experiment. This accuracy is obtained from the comparison of the angular velocity (rpm) of the wheels on the modeling tool from sensor readings and the angular velocity measured on a standard tool (Tachometer). The test results were carried out for ten trials. Experiments carried out include angular velocity on the sensor, and angular velocity on the tachometer.

accuracy is stating the degree of similarity within a group of measurements or a number of instruments. In other words, accuracy is the suitability between the desired will and the reality of the results obtained for certain goals. Accuracy is a factor that is needed by someone to achieve the desired target. Accuracy relates to one's desire to give direction to targets with specific aims and objectives [19]. For data on the accuracy of measuring angular velocity in concentric motion, it can be described in Table 3.

Table 3. Data on Accuracy of Angular Speed Measurement on Concentric Wheel Motion

Ω (rpm) input	Wheel 1			Accuration ω_1 (%)	Wheel 2			Accuration ω_2 (%)
	ω_1 (TM)	ω_1 tool (RL)	V_1		ω_2 (TM)	ω_2 tool (RL)	V_2	
40	39.6	41.80	0.29	94.45	41.9	40.76	0.19	97.27
50	50.0	48.86	0.33	97.72	49.6	51.14	0.22	96.89
60	58.7	61.10	0.42	95.91	61.4	62.90	0.27	97.55
70	69.2	70.67	0.48	97.87	68.7	69.33	0.32	99.08
80	79.9	80.65	0.54	99.06	80.9	79.35	0.36	98.08
90	87.1	91.93	0.63	94.45	90.1	92.07	0.41	97.81
100	100.4	101.87	0.71	98.53	99.8	101.13	0.46	98.66
110	109.2	110.98	0.76	98.36	110.1	109.02	0.50	99.01
120	121.7	119.73	0.82	98.38	119.9	120.22	0.54	99.73
	Average			**97.19**				**98.23**

Based on Table 3, the accuracy of the wheel motion is centered on the circular motion modeling of the connected wheel with 9 variations of angular velocity, which has a fairly good accuracy. The measurements carried out obtained an average accuracy on wheel 1 of 97.19%, on wheel 2 the average accuracy was 98.23%. The data with the highest percentage for one wheel is 99.06% with an angular velocity of 80 rpm and a tool reading of 80.65 rpm. The data obtained is compared with a standard measuring instrument in the form of a tachometer where from the data it can be stated that when the input speed is 70 rpm the data shown by the tachometer for wheel one is 69.2 rpm on wheel two at 69.33 rpm. %. Data with the highest percentage for wheel two is 99.73% with an angular velocity of 120 rpm and a tool reading of 120.22 rpm. From the data obtained, it can be concluded that in the motion of the wheel concentric, the angular velocity on wheels 1 and 2 is the same, while the linear speed on wheels 1 and 2 is different.

The accuracy of measuring the angular velocity of the connected wheel motion is obtained by varying the input value of the angular velocity of the wheel. The readings on the sensor and standard measuring device (tachometer) are compared to obtain the percentage of error from the data. The measurements were carried out 9 times with a data range of 40 rpm to 120 rpm. Data for the accuracy of measuring angles in the motion of the wheel in relation to the rope can be described in Table 4

Table 4. Data on Accuracy of Angular Velocity Measurements in Wheel Motion with Ropes

Ω (rpm) input	Wheel 1			Accuration ω_1 (%)	Wheel 3			Accuration ω_2 (%)
	ω_1 (TM)	ω_1 tool (RL)	V_1		ω_2 (TM)	ω_2 tool (RL)	V_2	
40	40.6	42.52	0.29	95.27	69.8	70.71	0.32	98.69
50	49.7	50.48	0.35	98.43	81.4	82.03	0.37	99.22
60	61.6	61.02	0.42	99.05	95.3	96.22	0.43	99.03
70	72.4	70.13	0.48	96.86	112.8	114.66	0.51	98.35
80	80.8	79.98	0.54	98.98	125.9	126.28	0.57	99.69
90	88.7	90.73	0.63	97.71	144.0	145.63	0.65	98.86
100	99.4	98.33	0.67	99.89	156.4	154.05	0.69	98.49
110	111.4	111.71	0.77	99.72	174.1	173.07	0.78	99.41
120	119.9	121.59	0.83	98.59	190.4	188.66	0.84	99.08
Average				**98.28**				**98.98**

Based on Table 4, the data on the accuracy of the motion of the wheel with the rope in the circular motion modeling of the wheel is associated with 9 variations of angular velocity, which has a fairly good accuracy. The measurements carried out obtained an average accuracy on wheel 1 of 98.28% on wheel 3 the average accuracy was obtained 98.98%. Data with the highest percentage for one wheel is 99.89% with an angular speed of 100 rpm and a tool reading of 99.4 rpm. The data obtained is compared with a standard measuring instrument in the form of a tachometer where from the data it can be stated that when the input speed is 80 rpm the data indicated by the tachometer for one wheel is 80.8 rpm and for three wheels it is 126.28 rpm. Data with the highest percentage for three wheels is 99.69% with an angular speed of 80 rpm on one wheel connected to the three wheels using a rope of 126.28 rpm. For wheels connected by a rope, the linear speed is the same, so to find the angular speed of the tri-cycle, it is the angular velocity of the wheel multiplied by the radius of the first wheel divided by the size of the radius of the tricycle. This indicates that the designed experimental set has results that are close to the tachometer readings. From the above data it can be concluded that in the motion of the wheel with the rope the angular velocity on wheels 1 and 3 is different, while the linear speed on wheels 1 and 3 is the same.

The precision of the measurement is the similarity of the values of a group of measurements. The accuracy of the angular velocity of the connected wheel motion was obtained by repeating measurements 10 times at an angular velocity of 45 rpm. The average of repeated measurements is compared to the actual data to get the percentage error. The precision of the angular speed data of 45 RPM on the center wheel motion can be described in Table 5.

Table 5. Precision of 45 RPM Angular Speed on Concentric Wheel Motion

Data	Precision			
	Wheel 1		Wheel 2	
	v1(m/s)	ω 1 (rpm)	v2 (m/s)	ω 2(rpm)
	0.651	95	0.427	95
1	0.65	95.46	0.43	96.54
2	0.66	96.57	0.43	95.98
3	0.66	95.63	0.42	94.37
4	0.65	95.53	0.43	96.49
5	0.64	94.61	0.42	95.32
6	0.66	95.54	0.43	96.21
7	0.66	96.45	0.43	97.13
8	0.64	94.76	0.45	97.05
9	0.65	95.96	0.42	94.34
10	0.65	94.84	0.43	95.16
$\overline{X}$	**0.652**	**95.535**	**0.429**	**95.859**
% Precision	**99.84**	**99.43**	**99.53**	**99.09**

Based on Table 5, the data of the precision of the concentric wheel motion in modeling the circular motion of the wheel associated with 10 speed variations has a fairly good precision. The measurements carried out obtained the precion of the angular velocity and linear speed on wheel 1 of 99.43% and 99.84%. On wheel 2 the precision on angular speed and linear speed is 99.09% and 99.53%. Based on the data obtained, it can be stated that the angular velocity is the same for the central wheel, while the linear speed is different.

The precision of the angular velocity of 45 RPM on the motion of the wheel with the rope was obtained by repeated angular velocity measurements 10 times. The average obtained from repeated measurements is compared with the actual data, so that the percentage of error is obtained. The following is the angular precision of 45 RPM on the motion of the wheel with the rope in Table 6.

Table 6. Precision of Angular Speed Of 45 RPM on Wheel Motion with Rope

Data	Precision			
	Wheel 1		Wheel 3	
	v1(m/s)	ω 1 (rpm)	v2 (m/s)	ω 2(rpm)
	0.651	95	0.651	144.70
1	0.65	94.25	0.65	144.63
2	0.65	95.51	0.68	150.30
3	0.64	94.51	0.66	147.01
4	0.66	95.79	0.66	147.12
5	0.66	96.15	0.67	148.83
6	0.66	97.36	0.68	151.28
7	0.65	94.22	0.66	146.65
8	0.65	95.36	0.66	146.25
9	0.65	94.58	0.66	147.11
10	0.65	95.23	0.67	149.90
$\overline{X}$	**0.652**	**95.296**	**0.665**	**147.908**
% Precision	**99.84**	**99.68**	**97.84**	**97.78**

Based on Table 6, the precision of the data for the motion of the wheel with the rope in the circular motion modeling of the connected wheel with 10 variations of velocity was has a fairly good precision. The measurements carried out obtained the precision of the angular velocity and linear speed on wheel 1 of 99.68% and 99.84%. On wheel 3 the precision on angular speed and linear speed is 97.78% and 97.78%. Data is taken from sensor measurements mounted on the tool. This indicates that the experimental set designed to have close to accurate results. Based on these data, it can be explained that the wheels are connected by a rope, the angular velocity of each wheel is different, while the linear velocity is the same.

The data obtained in the test for this experimental activity are measurements on the experimental set. This test is carried out by measuring the physical quantities contained in the wheel motion experiments related to each wheel. On one wheel with a diameter of 13.1 cm which is directly connected to the stepper motor and concentric with the two wheels. The results of reading physical quantities with an input of 45-105 rpm on one wheel are in Table 7.

Table 7. Data Wheel One and Wheel Two Measurement Data on A Set of Concentric Wheel Motion Experiments.

Wheel 1							
NO	**ω Input (rpm)**	**Tool (rad/s)**	**Tool (rpm)**	**f (Hz)**	**T (s)**	**V (m/s)**	**a (m/s²)**
1	**45**	4.81	45.92	0.77	1.31	0.31	1.51
2	**55**	6.01	57.44	0.96	1.04	0.39	2.37
3	**65**	6.86	65.50	1.09	0.92	0.45	3.08
4	**75**	7.94	75.82	1.26	0.79	0.52	4.13
5	**85**	9.07	86.64	1.44	0.69	0.59	5.39
6	**95**	9.96	95.15	1.59	0.63	0.65	6.50
7	**105**	10.90	104.14	1.74	0.58	0.71	7.78
Wheel 2							
NO	**ω Input (rpm)**	**Tool (rad/s)**	**Tool (rpm)**	**f (Hz)**	**T (s)**	**V (m/s)**	**a (m/s²)**
1	**45**	4.81	44.08	0.77	1.31	0.21	0.99
2	**55**	6.01	56.56	0.96	1.04	0.27	1.55
3	**65**	6.86	67.50	1.09	0.92	0.29	2.02
4	**75**	7.94	77.18	1.26	0.79	0.34	2.71
5	**85**	9.07	85.36	1.44	0.69	0.39	3.54
6	**95**	9.96	96.85	1.59	0.63	0.43	4.26
7	**105**	10.90	105.86	1.74	0.58	0.47	5.11

Based on table 7 it can be described that the values obtained from the measurement results of the one wheel and two wheels show that the angular velocity of each wheel can be said to be almost the same while the linear speed is different. These results indicate that the system is working as it should and these results are proven to be in accordance with the existing theory where the angular velocity of the concentric wheels is the same.

Testing activities for one- and three-wheeled wheels in which the wheels are connected using a rope. The one wheel is connected directly to the TB-6600 motor driver as the main drive of the wheels, which is connected to the three wheels using a rope. The results of this experimental activity test are shown in Table 8.

Table 8. Wheel One and Wheel Three Measurement Data on the Experimental Set of Connected Wheel Motion using a Rope.

Wheel 1							
NO	**ω Input (rpm)**	**Tool (rad/s)**	**Tool (rpm)**	**f (Hz)**	**T (s)**	**V (m/s)**	**a (m/s²)**
1	**45**	4.81	45.92	0.77	1.31	0.31	1.51
2	**55**	6.01	57.44	0.96	1.04	0.39	2.37
3	**65**	6.86	65.50	1.09	0.92	0.45	3.08
4	**75**	7.94	75.82	1.26	0.79	0.52	4.13
5	**85**	9.07	86.64	1.44	0.69	0.59	5.39
6	**95**	9.96	95.15	1.59	0.63	0.65	6.50
7	**105**	10.90	104.14	1.74	0.58	0.71	7.78

Wheel 3							
NO	**ω Input (rpm)**	**Tool (rad/s)**	**Tool (rpm)**	**f (Hz)**	**T (s)**	**V (m/s)**	**a (m/s^2)**
1	**45**	7.32	75.29	1.17	0.86	0.34	2.67
2	**55**	9.16	92.21	1.46	0.69	0.41	4.00
3	**65**	11.00	106.47	1.75	0.57	0.48	5.34
4	**75**	12.09	121.07	1.92	0.52	0.54	6.91
5	**85**	13.81	132.98	2.20	0.45	0.60	8.33
6	**95**	15.17	148.03	2.42	0.41	0.67	10.32
7	**105**	16.60	159.88	2.64	0.38	0.72	12.04

Based on table 8 it can be explained that the values obtained from the measurement results of one wheel and three wheels. The results of measurements and readings on the tricycle connected using a rope with this one wheel obtained the value of the physical quantity issued where the linear speed is the same as the first wheel and the angular velocity is different. On wheels one and two wheels that are unidirectional, the angular velocity values are the same and the linear speeds are different. This activity shows that the results obtained are correct and in accordance with the existing theory.

Based on the analysis that has been carried out, it can provide research results that are in accordance with the research objectives. The analysis was carried out using tables and figures. The research results obtained are the performance specifications of the components of the linked wheel drive experimental system, the results of the precision and accuracy test of the hooked wheel drive system, and the test results of the hooked wheel drive system for experimental activities.

The results of the first test are the performance specifications of the components of the associated wheel drive experimental system. First, the performance test results on the stepper motor seen from the data obtained have worked properly where when data was entered at 115 rpm the stepper motor moved at 114.35 rpm. The second is the performance results of NodeMCU and LCD, here the LCD has displayed the data as read by the tool because when the angular velocity data is entered at 80 rpm, the reading result on the LCD is 80.71 rpm. The three results of the performance test on the power supply, these results are obtained from measurements from the power supply section, the results measured are the output voltage, output current, supply power using a multimeter and the results obtained are displayed in this research. The results of the on-screen display performance test can be seen on the website page which can be accessed on a smartphone or laptop connected to the internet via the website domain. These results show the physical quantities on each wheel and also show a video of how the related wheel motion system works.

The second result is the accuracy and precision of the associated wheel motion system. Accuracy is the level of suitability or closeness of a measurement result to the actual value[24]. The value of the accuracy of measuring the stapper motor speed control is to compare the measured data with a standard measuring instrument (tachometer). The data obtained is close to accurate, where the error percentage is very small. The accuracy of the measurement is the similarity of the values of a group of measurements. Accuracy data on the angular speed of the stapper motor is obtained accurately, because the average of several data retrieval is close to the actual data. From the accuracy and precision data, it can be concluded that the stapper motor is a tool that can be controlled to obtain angular velocity. So the stapper motor is a good tool to use for experimental wheel motion experiment systems.

The third result is the experimental wheel motion test. The data obtained in this test is to prove whether the results we get are in accordance with the existing theory. The motion on the concentric wheel for one and two wheels has the same angular velocity on both wheels, while the linear speed is different for each wheel. The motion of the wheels is related to the rope on one wheel and three wheels have the same liner speed, while the angular speed on each wheel is different[25].Through the results of the accuracy and precision of the modeling tool, it can be concluded that using the wheel motion modeling tool in contact using a remote laboratory to get data that is close to accurate.

In this study there are three drawbacks. The first drawback is that the delay displayed on the computer/smartphone display is quite long. When the value is inputted on the Web, it takes about 5-8 seconds to transmit data to the experimental device so that the tool can move. As for the display on the web to display the movement of the rotating wheels on the experimental set of tools, it has a delay time of around 25-30 seconds so that it appears rotating on the experimental web screen tool. This can also be affected by how fast or slow the internet is being used.

The drawback is that the two motors do not support rotating at low and too high angular speeds with values below 40 rpm and above 340. This is due to the limitation of the stapper motor's rotational speed capability. The solution to this problem can use a motor that can rotate without any minimum and maximum limits.

The third drawback of this related wheel motion modeling tool is that the data recording of practicum results for praticing is only displayed as limited to the last data entered. The recording of the practicum results cannot be displayed in its entirety and also cannot record when and who last did the practicum.

The advantages of the wheel motion experiment system in relation to this remote laboratory are that it is easy to control where the control of the experimental set can be carried out on a laptop or mobile phone, a queuing system on the web that helps users to take turns using the experimental set, the physical quantities displayed are clear, more complete measurement results from previous studies where the measurement results display period, frequency, angular velocity (RPM), angular velocity (RPS), linear velocity and centripetal acceleration.

IV. CONCLUSION

Based on the results of testing and data analysis as well as discussion of the wheel motion experimental instrument associated with controlling the stapper motor speed, the first conclusions can be formulated. has worked properly. The second is the performance results of NodeMCU and LCD, here the LCD has displayed the data according to what was read by the tool because when the angular velocity data is entered at 60 rpm, the results are read on the LCD at 61.54 rpm. The results of the on-screen display performance test can be seen on the website page which can be accessed on a smartphone or laptop connected to the internet via the website domain. These results show the physical quantities on each wheel and also show a video of how the related wheel motion system works. Second, the results of the test for the accuracy and accuracy of the related wheel motion system. The accuracy of the related wheel motion is obtained by comparing the output results read by the system with the values read by a standard measuring instrument, namely a tachometer. These results display the physical quantities for each wheel and also show a video of how the connected wheel motion system works. System test results for experimental activities on connected wheel motion. The data obtained in this test is to prove the results of existing theories. The test results for the central wheel seen from the data show that the angular speed of the central wheel is almost the same, and the linear speed is different. The results for the wheels connected by ropes on one wheel and three wheels showed that the angular speed was different and the linear speed was almost the same. The test results for this experimental activity were proven to be in accordance with existing theory, where for a central wheel the angular speed of the wheel is the same and for wheels connected by a rope the linear speed is the same.

REFERENCES

[1] Y W Etistika, Dwi A S, and Amat N, "Transformasi Pendidikan Abad 21 Sebagai Tuntutan," *J. Pendidik.*, vol. 1, pp. 263–278, 2016.

[2] S. K. Handayani and M. Satyadini, "Rancangan Remote Laboratory di Program Studi Biologi Fakultas Matematika dan Ilmu Pengetahuan Alam Universitas Terbuka (Design of Remote Laboratory at the Department of Biology , Faculty of Mathematics and Natural Sciences , Universitas Terbuka)," *Semin. Has. Penelit. Univ. Terbuka 2018*, no. October, pp. 1–28, 2018.

[3] K. Amalia, S. Saparahayuningsih, and A. Suprapti, "Meningkatkan Kemampuan Sains Mengenal Benda Cair Melalui Metode Eksperimen," *J. Ilm. POTENSIA*, vol. 3, no. 2, pp. 1–10, 2018.

[4] N. E. Hayuningtyas, A. Wijayanti, and M. Muhajir, "Metode Eksperimen Untuk Meningkatkan Hasil Belajar Dan Jiwa Kewirausahaan Siswa Sekolah Dasar," *Paedagogia*, vol. 20, no. 2, p. 150, 2018.

[5] F. S. Anggraini, Y. Sugiarti, and D. Cakrawati, "Pembelajaran Dengan Pendekatan Saintifik Menggunakan Media Audio Visual Pada Kompetensi Dasar Pengemasan," *Edufortech*, vol. 3, no. 1, 2018.

[6] A. Y. Kapi Kahbi, N. Osman, R. Z. Ramli, and J. M. Taib, "Multimedia education tools for effective teaching and learning," *J. Telecommun. Electron. Comput. Eng.*, vol. 9, no. 2–8, pp. 143–146, 2017.

[7] C. Putri and Asrizal, "Pengembangan Tool Pemodelan Gerak Melingkar Beraturan Dengan Pengontrolan Laju Motor DC Berbantukan Analisis Video Tracker," *Pillar Phys.*, vol. 12, pp. 61–69, 2019.

[8] Asrizal, V. Lorenza, and Yohandri, "Digital experimental system of connecting wheel motion with remote laboratory based on website," *J. Phys. Conf. Ser.*, vol. 2309, no. 1, 2022.

[9] Yohandri, Asrizal, and I. Chazanah, "Digital experiment system of uniform circular motion with remote laboratory based on website," *J. Phys. Conf. Ser.*, vol. 2309, no. 1, 2022.

[10] S. Nurachmandani, *Setya Nurachmandani*. 2009.

[11] I. Fitriyanto and I. Sucahyo, "Penerapan Software Tracker Video Analyzer pada Praktikum Kinematika Gerak," *J. Inov. Pendidik. Fis.*, vol. 05, no. 03, pp. 92–97, 2016.

[12] M. Yulkifli, Anwar, Z., Djamal, "Desain Alat Hitung Kecepatan Sudut Berbasis Sensor Mangetik Fluxgate," *J. Sainstek*, vol. 1, no. 2, pp. 79–90, 2009.

[13] Indriani Pamungkas, “Pengembangan Alat Peraga Rotating Wheels (Aprw) Pada Materi Gerak Melingkar Beraturan Untuk Siswa Sma,” 2018.

[14] I. Pendidikan, B. Ilmiah, R. Industri, and P. Ipa, “Seminar Nasional Pendidikan Fisika 2019 Seminar Nasional Pendidikan Fisika 2019,” vol. 4, no. 1, pp. 92–96, 2019.

[15] W. Audia, Mairizwan, R. Anshari, and Yulkifli, “Automatic Transfer Switch Solar Cell Inverter System Based on Android Application,” *J. Phys. Conf. Ser.*, vol. 2309, no. 1, 2022.

[16] A. Deris, “Sistem Informasi Darurat Pada Mini Market Menggunakan Mikrokontroler Esp8266 Berbasis Internet of Things,” *Komputasi J. Ilm. Ilmu Komput. dan Mat.*, vol. 16, no. 2, pp. 283–288, 2019.

[17] X. Chen, G. Song, and Y. Zhang, “Virtual and remote laboratory development: A review,” *Proc. 12th Int. Conf. Eng. Sci. Constr. Oper. Challenging Environ. - Earth Sp. 2010*, vol. 41096, no. March 2010, pp. 3843–3852, 2010.

[18] F. Y. Limpraptono, E. Nurcahyo, A. Faisol, M. Ajiza, and D. K. Sunaryo, “Development Architecture of Remote Laboratory as Learning Solution in Industrial Revolution 4.0 Era,” *J. Ind. Intell. Inf.*, vol. 8, no. 2, pp. 49–53, 2020.

[19] V. Ayudyana and Asrizal, “Rancang Bangun Sistem Pengontrolan pH Larutan Untuk Mahasiswa Fisika , FMIPA Universitas Negeri Padang Staf Pengajar Jurusan Fisika , FMIPA Universitas Negeri Padang,” *Pillar of PhysicsPhysics*, vol. 12, pp. 53–60, 2019.

[20] I. Solikhin, M. Sobri, and R. Saputra, “Sistem Informasi Pendataan Pengunjung Perpustakaan (Studi kasus : SMKN 1 Palembang),” *J. Ilm. Betrik*, vol. 9, no. 03, pp. 140–151, 2018.

[21] R. Riska and H. Alamsyah, “Penerapan Sistem Keamanan Web Menggunakan Metode Web Aplication Firewall,” *J. Amplif. J. Ilm. Bid. Tek. Elektro Dan Komput.*, vol. 11, no. 1, pp. 37–42, 2021.

[22] J. Smith, “Developmental Research,” *Safflower*, pp. 142–184, 1996.

[23] W. U. N. D. Praxis and B. Seller, *Service Engineering – Wissenschaft Und Praxis : Zwei Seiten Derselben*.

[24] I. Fauzi, R. Rasyid, L. Elektronika, J. Fisika, K. Unand, and L. Manis, “Rancang Bangun Alat Ukur Dioptri Lensa Kacamata Untuk Penderita Miopi Dan Hipermetropi Dengan Penerapan Perspektif Visual Digital Berbasis Arduino Mega2560,” vol. 12, no. 4, pp. 651–657, 2023.

[25] I. Sya’roni, M. A. N. Putri, and W. Devianti, “Analisis Respon Siswa Terhadap Pembelajaran Fisika Materi Gerak Melingkar Menggunakan Alat Peraga Rotating Wheels Berbasis Arduino,” *Pros. Semin. Nas. Fis.*, vol. 5, pp. 1–7, 2021.