Fabrication of Digital Harmonic Vibration Practicum Using Phototransistor Sensor with Arduino-Uno Microcontroller

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Abstract: The problem in the harmonic vibration practicum is in calculating time accurately. Commonly, the time counter used was a stopwatch, but it was unable to provide valid data. As a result, the student has difficulty seeing the relationship between concepts with practical results in the laboratory. To overcome these problems, in this study, we developed a harmonic vibration practicum tool that is equipped with a digital timer using an Arduino Uno microcontroller as a light sensor. An Arduino can be programmed via a PC according to the wishes of the developer. This study was development research using a 4-D model (Define-design-develop-dissemination). The define and design stages respectively to find problems in the harmonic vibration practicum tool. The tool is finally designed and then calibrated, validated, and practical. The calibration results show that the percentage difference for repetition measurement and comparison that values with theory was 0.008% and 3.98%, respectively. In addition, the validation results show an average percentage of 87% or very valid. For practicality, the result through a limited test of Physics students of IAIN Batusangkar in the second semester shows a very practical response with a percentage of 85.96%. Due to time constraints, the dissemination stages have not been carried out in this study.

Keywords: Harmonic vibration; Arduino Uno; Microcontroller; stopwatch

Introduction

The concept of physics was built from experiments that gave birth to statements, formulations, and lastly, it rose the concept. In addition, experiments conducted by practitioners are also useful for proving existing theories. To generate and prove the correct concept, we need a practical tool that is also valid and fast response to changes in physical quantities that exist during the practicum or experiment (Harmita, 2012). To carry out practical easily with high data accuracy, it is necessary to develop practicum tools such as changing shapes, simplifying processes, digitizing time recording, and others (Trianto, 2009). Especially for time recording

tools, practicum tools in schools and universities still use a lot of "stopwatches", where the "start/on" and "stop/off" buttons are pressed at the beginning and the end of the practicum process.

Among the practicum equipment in schools that require time during the experimental process is straight motion changing regularly (GLBB) (Deesera et al., 2017), free fall movement (GJB) (Maiyena, Imamora, & Ningsih, 2018), simple harmonic motion (GHS) (Dewi, 2014), viscosity, etc. In the GHS experiment, the time of one vibration was recorded by using the manual stopwatch. This condition needs to be optimized because if we use a stopwatch for a short track, the time recording is less accurate and causes large errors in the

measurement. Normally, the start button of stopwatch is pressed when the pendulum is released and pressed again to stop when the pendulum has swung as much as desired. This condition is prone to errors because if the practitioner is late in pressing the start or stop button, it will cause large errors, especially in time recording (Farasdaq; Humaira, 2016).

Developments that have been carried out by Sukindar, Kartika, and Untoro (2017) using a phototransistor sensor with an Arduino microcontroller for the experiment of the moment of inertia. We categorized these practicum tools as good according to several media, materials, and physics teachers. The Arduino sensor used is an electronics kit as the key component where it can be programmed using a computer (Syahwil, 2013). If the sensor is installed as a timer in the GHS experiment, we positioned the sensor in the middle of the pendulum. If the object passes through the sensor three times, it is equal to one vibration. This is done repeatedly with as many vibrations as desired, and then the recorded time will be displayed on the LCD screen. With such developments, it is hoped that the GHS experiment can provide accurate data and successfully prove the theory.

Based on this phenomenon, it is reported that we have developed a digital GHS (DGHS) practicum tool that was facilitating recording time. A DGHS practicum tool has been developed by using an Arduino-based phototransistor sensor and has received recognition as a validity, practicality tool (Riduwan, 2010) and a very convincing calibration tool. This is proven by the truth of the data generated from the practicum and validated by three validators giving a very valid assessment with an average percentage of 87%. Meanwhile, in terms of the practicality of the DGHS practicum tools obtained from the responses of the second-semester Physics students of IAIN, Batusangkar also gave an assessment that the DGHS practicum tools developed were very practical to use with a percentage of 85.96%.

Method

This research is a Research and Development (R&D using a 4-D model developed by Thiagarajan, which consists of (1) definition, 2) design, 3) development and 4) dissemination. Technically, these four steps are described in Figure 1. At the definition stage, the condition of the simple harmonic vibration (GHS) practicum tool has been known that needs to be developed to produce a valid and practical tool. At the design stage, a phototransistor circuit schematic is described as a timer sensor used. The installation of the circuit components to the PCB board using solder, and we paired the components as in Table 1. Lastly, we then

connected to the Arduino Uno (Rinanthy, 2016) before placing it in the packaging (see Figure 2).
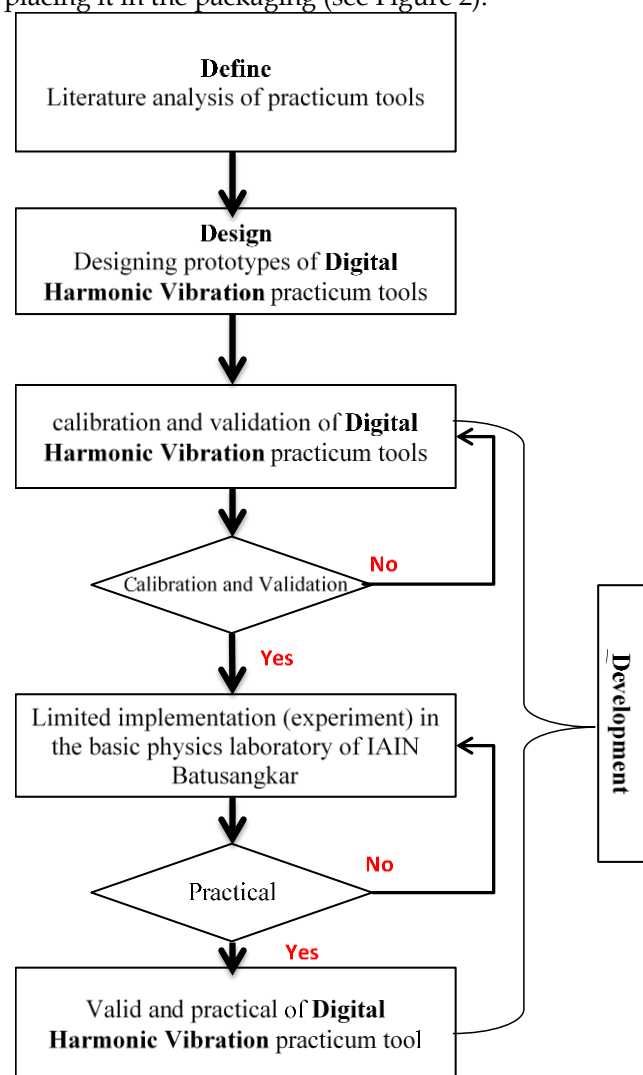

Figure 1. The development stage of the digital harmonic vibration practicum tool.

The calibration test is one of the steps in the development stage besides validating and practicality. This calibration is useful for proving the value of the acceleration of gravity from the data obtained from the DGHS practicum tool comparing with the earth's gravity (9.8 m/s^2). There are some calibrated aspects, namely frequency of use, data stability, usage conditions, and error limits. We validated this DGHS tool in 2 fundamental aspects, including content validation and construct validation. Content validation should determine whether the resulting DGHS practicum tool is under the concept of gravity. Meanwhile, construct validation aims to see the suitability of the practical tools with the basic competencies that have been set. Experts carried validation out by filling out a validation sheet. In the last stage, we also conducted the response test of physics students at IAIN Batusangkar in the second semester on the practicality of the DGHS practicum tool.

Table 1. Tools and materials are needed in the development of DGHS practicum tools (Humaira, 2016).

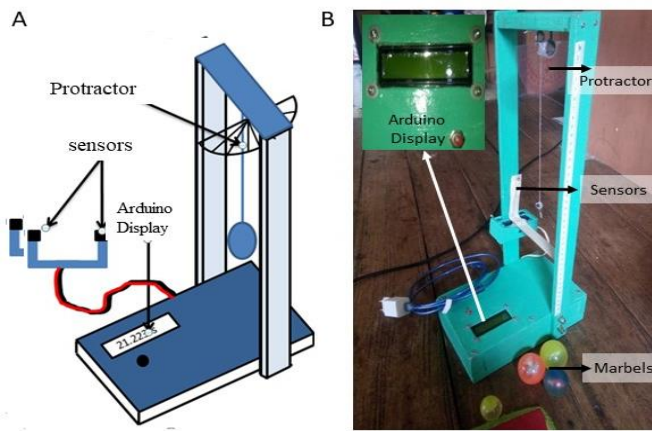| No	Tool	Specification	Number of units)
1	Resistor	220 Ω	6
2.	Resistor	10 kΩ	2
3.	Resistor	82 Ω	1
4.	Resistor	300 Ω	2
5.	Transistor	2N 3906	1
6.	Phototransistor	-	1
7.	Infrared Diode	-	1
8.	IC	NE 555	1
9.	Microcontroller	Arduino Uno	1
10.	LED	Orange color	4
11.	Switch	On/Off	3

Figure 2. A. Sketch and B. Digital harmonic vibration (DGHS) practicum tool

Result and Discussion

We report the results of the four stages of developing the DGHS practicum tool in this section. At the definition stage, information was obtained that the harmonic vibration practicum tool in the school still uses a stopwatch in determining the time required to perform the vibration. The practitioner will start the time recording by pressing the start button when it starts and the stop button at the end. This condition opens the opportunity for difficulty in getting the correct data, especially recording the time to make one vibration validly. To cover this weakness, it is necessary to add an automatic switch device by utilizing an Arduino-based phototransistor sensor as a start-stop of a stopwatch so that the vibration time of objects on the pendulum can be monitored accurately.

We then outlined the results in the design stage of a practical tool using an Arduino-based phototransistor sensor and a practical guide for simple pendulum materials. The design is more focused on making practical tools using a phototransistor sensor based on Arduino Uno, while the design of a practicum guide is used to help practitioners implement this practicum

effectively and efficiently. We design the practicum tool in a simple form so that it is easy to use, as shown in Figures 2A and 2B. At the development stage or stage 3, we have carried several series of tests out to test the validity of the data generated by the DGHS practicum tool. Among these tests are calibration, validation and practical which are discussed one by one on the following description.

Calibration

Practical Tool Calibration Using Arduino-Based Phototransistor Sensor

We did calibration to adjust the DGHS tool that has been designed with existing products. In this practical tool using an Arduino-based phototransistor sensor, what it calibrated is a timer. We carried calibration out in two stages: the measurement of repeated time and comparing the calculated value of practicum gravity with the value of the earth's gravity (see Table 2).

Table 2. The result of Timer Calibration by Comparing the Value of the Earth's Gravity Coefficient.

No	Time (s)	g-practice (g = ± g) (m/s^2)	% Error repeated time measure ment	g-theory (m/s^2)	% Error
1	9,16				
2	9,15				
3	9,15	9.41±0.20	0.08%	9.80	3.98%
4	9,16				
5	9.16				
5	9.16				

Description: Mass of marbels = 0.045 kg, $\theta = 10°$, $l = 0,20\ m$, N = number of vibrations (10 times)

The data in Table 2 shows that the results of the calibration of the time calculation on the DGHS practicum tool using an Arduino-based phototransistor sensor obtained through experiments on a simple pendulum with the mass of ball was 0.045 kg, a pendulum string length of 0.20 m, and an angle of 0.045 kg. 10°. The result of repeated time measurement error is 0.08%, and the value of gravity is 9.41 ± 0.30. After being compared with the value of earth's gravity with this value, resulting from an error percentage of 3.98%. This data shows that the timer on the DGHS practicum tool is well-calibrated (Rinanthy, 2016).

Measurement

Data on Experimental Results of DGHS Practicum Tool.

At this stage, we have carried out testing on the DGHS practicum tool. The experimental stage of data collection is to test the suitability of the theoretical relationship with the data obtained from the developed

DGHS practicum tool. Proof of the suitability of the data for the practicum guide, which is the effect on rope length, load mass, and angle on the vibration period (see Table 3).

Table 3. The Effect of Rope Length on the Pendulum Period.

No	Rope Length (m)	Time of object swing 10 vibration (s)	T(s)	T^2(s)
1	0.1	6.28	0.63	0.40
2	0.15	7.66	0.77	0.59
3	0.2	8.88	0.89	0.79
4	0.25	9.96	1.00	1.00
5	0.3	10.97	1.10	1.20

Description: Mass of marbels = 0.045 kg, $\theta = 20°$, N = number of vibrations (10 times)

From Table 3. we can see that the period value increases with the increase in the pendulum's rope length. We can also see the relationship between the variation of the load mass and the period of the pendulum vibration (see Table 4). We also can see that there is no significant shift in the value of the vibration period to the value of the mass of marbles.

Table 4. Relationship between mass to the period of vibration.

Mass Load (Kg)	T_1(s)	T_2(s)	T_3(s)	T_4(s)	T_5(s)	$\bar{T}$(s)
0.007	0.851	0.85	0.85	0.851	0.85	0.85
0.019	0.888	0.888	0.888	0.888	0.888	0.888
0.036	0.893	0.893	0.893	0.893	0.893	0.893
0.047	0.865	0.865	0.865	0.865	0.864	0.865
0.052	0.897	0.897	0.897	0.897	0.897	0.897

Description : $\theta = 20°$, N = number of vibrations (10 times) $l = 20\ cm = 0,2\ m$

Besides, we can also see that the relationship between the period and the object's mass does not affect the gravity value. The period obtained at various angles of rope deviation resulting in a gravity value is relatively constant (see Table 5). This illustrates that there is no significant effect of the period value on the rope deviation angle. However, the time to make one vibration with an increasing angle of deviation of the rope was also increasing (Tipler, 1998).

Table 5. Relationship between the angle formed by the rope with the period.

No	angle (θ)	T(s)	T²(s)²
1	50	0.900	0.838
2	70	0.910	0.848
3	100	0.915	0.865
4	120	0.920	0.883
5	150	0.925	0.918

Description : mass of marbels = 0.052 kg, l = 0,20 m, N = number of vibrations (10 times).

After the DGHS practicum tool was calibrated, we continue to the validation stage. We give validation instruments to 3 (three) validators, namely two physics lecturers and one physics teacher. Suggestions from the validator for adding units to the result display and the "many vibration" parameter on the LCD display already followed. The three validators gave a very valid DGHS practicum tool with a percentage of 87% (see Table 6).

Table 6. Results of Validation Analysis of DGHS Practical Tools Using Arduino-Based Phototransistor Sensors (Harmita, 2012).

Aspects that Validated	Validator			Num-ber	max score	%	Note
	1	2	3				
functionality	12	10	12	34	36	94.4	Very Valid
Convenience	13	13	16	42	48	87.5	Very Valid
Security	11	9	12	32	36	88.9	Very Valid
Aesthetics	15	12	15	42	48	87.5	Very Valid
Usage accuracy	13	10	15	38	48	79.2	Valid
Amount	64	54	70	188	216	87	Very Valid

The validation of the DGHS practicum tool using an Arduino-based phototransistor sensor get a percentage in the ranges of 79.2% to 94.4%. Overall, the practicum tool using an Arduino-based phototransistor sensor is classified as very valid, with an average percentage of 87%. Meanwhile, the results of the validation on the DGHS practicum guide for each aspect (from 79.2% to 87.5%) which was classified as very valid with an average percentage of 83.3%. The material in the practicum guide is under the achievement of practicum objectives. The writing of the practicum guide includes the format for writing the practicum guide. The suitability of the language used is communicative and in accordance with the heterogeneous abilities of practitioners.

To see the practicality of the practicum tool using an Arduino-based sensor, we conducted a trial on second-semester IAIN Batusangkar physics students through practical activities using a DGHS practicum tool using an Arduino-based phototransistor sensor. I gave ten practitioners to fill in the response into the questionnaire after carrying out the practicum and making observations. Data from the practitioner's response through the questionnaire to the practicality of practical tools using an Arduino-based phototransistor sensor can be seen in Table 7.

Table 7 shows that all aspects of the practicum tools, which were developed using Arduino Uno-based phototransistors get practical responses from the physics students with an average percentage was 85.96%. We can see, the easy read output data of a DGHS practicum tool get the highest percentage of 97.5% (Sulistiadji & Pitoyo, 2009). Besides, this condition can create a new atmosphere where students feel happy and easy to carry out practicum (percentage 95%) (Sanjaya, 2008). The

curiosity of students to understand the concept of DGHS is also getting better. In the end, students no longer think physics is difficult to understand because we have

presented the concepts and proofs through practical and valid experiments (Djamarah & Zain, 2006).

Table 7. The Results of the Questionnaire Response to the Practicality of Practicum Tools Using Arduino-Based Phototransistor Sensors.

No	Statement	Your opinion				Percentage (SS)	percentage (S)	amount score	percentage max
		SS	S	TS	STS				
1	I can understand the use of a simple pendulum practicum set based on an Arduino Uno microcontroller	4	6			40	60	34	85
2	I can understand the functions of the components in a simple pendulum practicum tool	5	5			50	50	35	87.5
3	It is easy for me to vary the distance of a simple pendulum practicum tool based on an Arduino microcontroller	2	8			20	80	32	80
4	I can easily read the output data of a simple pendulum practicum tool.	9	1			90	10	39	97.5
5	It becomes easier for me to carry out practicum by using a simple pendulum practicum tool	8	2			80	20	38	95
6	After using a simple pendulum practicum tool can improve my analytical skills	4	6			40	60	34	85
7	After using a simple pendulum practicum tool can improve my curiosity ability	4	6			40	60	34	85
8	After using a simple pendulum practicum tool, it is easier for me to understand the concept of physics	3	7			30	70	33	82.5
9	after using a simple pendulum practicum tool, I prefer to study physics	3	7			30	70	33	82.5
10	After using a simple pendulum practicum tool, I am not longer think physics is difficult	4	6			40	60	34	85
11	After using a simple pendulum practicum tool, I am interested in learning more about physics	4	6			40	60	34	85
12	I can carry out pendulum practicum effectively using simple pendulum practicum tools.	3	7			30	70	33	82.5
13	I can carry out pendulum practicum efficiently using simple pendulum practicum tools.	4	6			40	60	34	85
Percentage									85.96

Conclusion

Based on the results, it can be concluded that the digital harmonic vibration (DGHS) practicum tool using an Arduino Uno-based phototransistor sensor has been successfully developed and calibrated. The results of calibration from repeated time and gravity values measurement were obtained with the percentage of error was 0.08% and 3.98%, respectively. We have also validated this product in terms of functionality, ease of operation, safety, aesthetics, and accuracy with an average percentage of 87% or very valid. Lastly, this practicum tool also received a very practical response from physics students at IAIN Batusangkar, with the

average percentage of practicality responses was 85.96%.

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