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Development of Practicum Tools for Measuring Temperature and Air Humidity Based on Microcontroller by Telemetric

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Abstract

The purpose of this research is to make a temperature measuring instrument for air temperature and humidity on the device using the DHT11 sensor as a temperature and humidity sensor for the object under study, the ATMega328P CH340G microcontroller as data processing and the Bluetooth HC-05 module as an intermediary communication between the device and a smartphone. , utilizing App Inventor technology as a means of information quickly and accurately. The research method used in this study is the research and development method or known as research and development (R&D). This measuring tool is made using the Arduino Uno R3 module, which is programmed using the Arduino programming language. Based on the results of the study, it can be concluded that: 1) The measuring instrument is designed to be able to measure temperature and humidity in a place/room continuously, 2) the system can provide precise and accurate information on the temperature and humidity of the device to the user. The additional result is that apart from practical measuring tools it can also be used as a wireless monitoring tool for temperature and humidity for swiftlet houses which is useful for solving temperature and humidity problems in swiftlet houses as well as outputs of Intellectual Property Rights Products.

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INTRODUCTION

Physics is a branch of science that studies matter and all physical activities of that material. Besides that, physics is also a natural science of matter and energy, such as heat, light and sound, that deals with matter, energy and their interactions. Meanwhile, according to [1] physics is the knowledge that describes the collective efforts, findings, insights and wisdom of humans.

Studying physics means understanding and knowing the physics concepts and then applying them in everyday life. Practicum is very closely related to learning physics. With practicum, students understand more quickly. This is because the concepts they learn are directly applied, and they are directly involved in the training.

All objects in nature are composed of a substance or matter. Living things are also composed of substances or matter. Every sense is composed of millions of particles. A substance can be divided into solids, liquids, and gases based on the constituent particles. A substance can be measured and studied without changing the composition or composition of the essence. Temperature is a physical quantity that expresses the degree of heat of a substance as measured using a thermometer. The unit of temperature commonly used is degrees Celsius (^{0}C) [2]. Temperature can also be interpreted as a physical property of an object that describes the average kinetic energy of the movement of molecules. The higher the air temperature, the lower the air humidity. This is due to the air's high temperature, and precipitation (condensation) molecules will occur. Air humidity is the concentration of water vapour in the air. This concentration figure can be expressed in absolute, specific, or relative humidity.

Measurement can be interpreted as giving a number to a certain attribute or characteristic possessed by a person, thing or certain object according to clear and agreed rules or

formulations. Measurement also compares a quantity measured with a measuring instrument used as a unit. So far, the temperature measuring instrument used is an alcohol or mercury thermometer. The alcohol and mercury thermometers used today for teaching temperature and heat have various weaknesses, including easily broken capillary pipes. Mercury is toxic, making it dangerous for the safety of students. Besides that, the disadvantage is especially in the reading of the scale because it is still in manual form with direct observation, so it is prone to random errors in the measurement results.

Science and technology have progressed, and we live in a technological era where all measuring instruments are completely digital. One of them is the measurement carried out by telemetry. Telemetry is the process of measuring the parameters of an object (object, space, natural conditions) whose measurement results are sent to another place by sending data either by cable or wirelessly [3]. In practice, this concept is applied in tool designs or projects that use sensors and microcontrollers to translate analog input into software systems to control the movement of electro-mechanical devices such as lights, motors and so on [4]. Because of this, researchers are trying to develop a practicum tool for measuring air temperature and humidity based on a telemetry microcontroller. The device is to be designed digitally and can measure two different variables in one measurement simultaneously so that temperature and humidity measurements during practicum can be done easily and quickly because the observations were made telemetry to see the measurement results.

The benefits of this research are to broaden researchers' insights and make it easier to practice temperature measurements, and the results obtained are more accurate. Based on the background stated above, the problem identified in this study is "How to develop a practicum tool for measuring temperature and humidity based on a microcontroller by telemetry?

METHOD

This research is known as Research and Development (R&D). This research method is used to produce certain products and tests the effectiveness of these products. The research on developing a microcontroller-based temperature-measuring practicum tool utilizing telemetry was adapted from the steps of the development research model by Borg and Gall [5]. The steps of the research model are as follows:

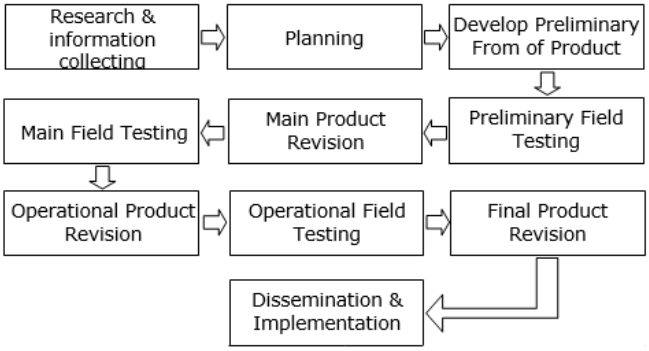

Figure 1. Steps to use the Research and development method.

In this study, not all of the R&D steps were carried out, only up to the limited test in step four, which was accompanied by the limited test results. This is due to the need for more time and expertise to carry out extensive implementation trials up to the Final Product Dissemination and Implementation steps. This first step includes need analysis, literature study, and required standard reports. After conducting a preliminary study, development can proceed to the second step, planning research. Research planning includes; 1) formulating research objectives; 2) estimating funds, manpower and time; 3) formulating the qualifications of researchers and forms of participation in research. This step includes; a. Determining the product design to be developed. At this stage, the researcher made a practicum tool for measuring temperature and humidity using telemetry on a microcontroller.

Designing the product to be made. The initial design of the product is as follows:

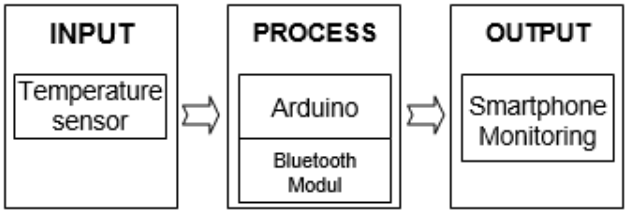

Figure 2. Product initial design

This research carried out many consultations with the mechanics of the tools to be made; b. Determine research facilities and infrastructure needed during the research and development process; c. They determine the stages of implementing the display test of practicum tools in the field;

d. Determine the task description of the parties involved in the research to make a practical device for measuring air temperature and humidity based on a telemetry microcontroller, and several steps are needed as follows;

Prepare the tools and materials used. The tools and materials to be used in this study are: DHT sensors 11, Arduino Uno, PCB board, and Smartphones. Make a simple practical tool design. Validating the tool on the validator to match the concept of temperature and humidity. One of the requirements for the tool to be validated is the calibration of the tool made. In this product, calibrate by clicking the "NOT CONNECT" option on the cell phone screen in the application. Conduct the Media Expert test, test the response of the Physics laboratory assistant through a questionnaire. Preliminary Field Test This step is a limited product trial. The researcher introduces a practicum tool and then provides a questionnaire about the feasibility of a practicum tool for measuring temperature and humidity based on a telemetry microcontroller. The respondent's questionnaire was used, namely the physics laboratory assistant's response scale questionnaire, which is then analysed by giving a score and making conclusions based on the questionnaire results and developing a practicum tool for measuring air temperature and humidity based on a telemetry microcontroller.

The development model in this study uses a procedural model, namely a descriptive model, showing the steps that must be followed to produce a product in the form of a practicum tool for measuring air temperature and humidity. This study's practicum tool development model uses steps adapted from Borg & Gall [5]. The research flow is designed to provide an overview, as shown in the flowchart in Figure 3.

This research was carried out in the Physics education laboratory of the Teacher Training and Education Faculty of Tadulako University, State High School 2 Palu, State High School 7 Palu and State High School 9 Palu. The subjects of this study were the physics education laboratory assistants of Teacher Training and Education Faculty of Tadulako University and physics teachers. Data collection techniques are ways of performing or capturing the results of the work of the mind, which are operationalized to an empirically realistic level to obtain reliable data. A good data collection method is needed.

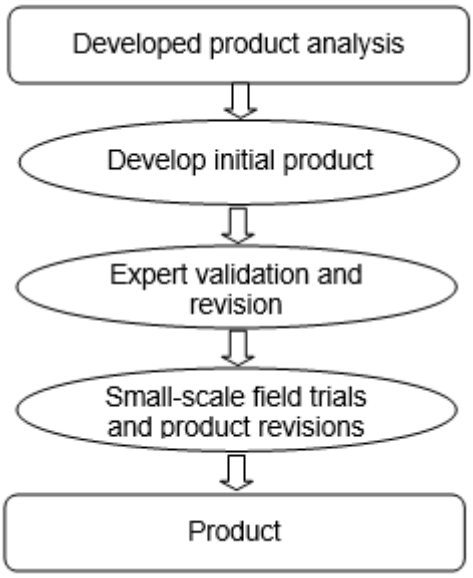

Figure 3. Model for developing a practicum tool for measuring air temperature and humidity based on a telemetry microcontroller

The data used are as follows: 1) Questionnaires are data collection tools containing several questions or statements that research subjects must answer. Questionnaires can reveal many things so that a lot of data/information is obtained in a short time. Based on their shape, questionnaires can be opened and closed. In this study, a closed questionnaire was used with a Likert scale type with a scale of 1 to 4. Very good is worth 4, good is worth 3, poor is worth 2 and very poor is worth 1. Closed questionnaires have answers that have been provided and do not allow respondents to add other information [6]. The questionnaire is a written question that is used to obtain information from respondents about matters relating to research activities. The indicators assessed in the questionnaire are; The quality of practicum tools, there are use of goods that are easily accessible, there is technical assistance in practicum tools in terms of the suitability of the device with the concept of physics; 2) Interviews are used as a data collection technique when research is about things from more in-depth respondents, and the number of respondents is small or limited. This study used unstructured interviews. Unstructured interviews are free interviews in which the researcher does not use interview guidelines that are arranged systematically and completely. This was done because structured questions already existed in the questionnaire. The researcher only wanted to know things

that could become critical and suggestions for the practicum media being developed.

A research instrument is a tool that can support several data that are assumed to be used to answer questions and test research hypotheses. The instrument used in this study was a questionnaire given to media experts, material experts, physics teachers, and lab assistants as the respondent. Data obtained through research instruments during the trial were analysed using descriptive analysis, describing the results of the development of learning media products in simple practicum devices. This analysis intends to describe the data characteristics of each variable. This way is expected to make it easier to understand the data for further processing. The results of the data analysis are used as a basis for revising the developed tool product. The steps for analysing the interview data are as follows: Data reduction, data presentation, and drawing conclusions/verification [7]. The type of qualitative data is changed to quantitative with the provisions in Table 1 and Table 2.

Table 1. Product Assessment Likert Scale Category

Information	Score
Very Good	4
Good	3
Poor	2
Very Poor	1

Table 2. Categories of Likert Scale Responses of Basic Physics Practice

Information	Score
Strongly Agree	4
Agree	3
Disagree	2
Strongly Disagree	1

The analysis technique used to analyse the validation data is calculating the average value. The determination of the intermediate value analysis technique is based on the opinion of [8], which states that to determine the final score rating for each research questionnaire item, the total value obtained is divided by the number of respondents who answered the assessment questionnaire. So, a formula is obtained to calculate the average value in Equation 1.

$$\bar{X} \frac{\Sigma x}{n} \quad (1)$$

Where $\bar{X}$ is the average value in each item question; Σx is the total value of all assessments in each question item; n is number of questions.

Then processing, the average value of the quality assessment aspects was obtained in qualitative form according to the assessment category criteria with the provisions in Table 3 and 4.

Table 3. Positive Statement Product Assessment Criteria

Interval Score	Category
$3{,}25 < \bar{X} \leq 4{,}00$	Very Good
$2{,}50 < \bar{X} \leq 3{,}25$	Good
$1{,}75 < \bar{X} \leq 2{,}50$	Poor
$1{,}00 < \bar{X} \leq 1{,}75$	Very Poor

Table 4. Criteria for the basic physics practice response categories for positive statements

Interval Score	Category
$3{,}25 < \bar{X} \leq 4{,}00$	Strongly Agree
$2{,}50 < \bar{X} \leq 3{,}25$	Agree
$1{,}75 < \bar{X} \leq 2{,}50$	Disagree
$1{,}00 < \bar{X} \leq 1{,}75$	Strongly Disagree

RESULT AND DISCUSSION

Result

A. Tool Quality Assessment By Experts

The results obtained were that for program design, the average score was 3.33, which was in the very good category. In the aspect of program quality, the average value obtained is 4.00 and is in the very good category. In the aspect of tool design, the average value obtained is 3.00 and is in a good category. In the aspect of tool quality, the value obtained is 4.00 and gets a very good category.

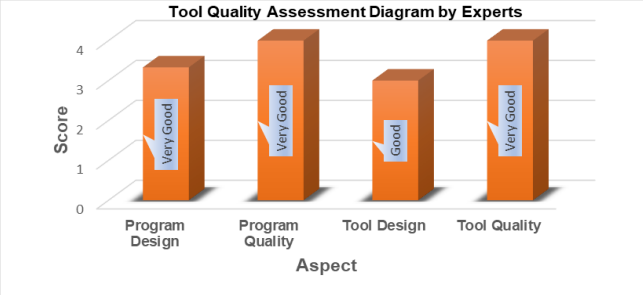

Figure 4. Tool Quality Assessment Diagram by Experts

As for suggestions and criticisms from expert validators, namely improving product quality, namely on the physical part of the tool so that a place or cover is made so that it is not easily damaged, the tool developed is very good.

The assessment results of the aspects in the laboratory manual, namely, the average value obtained for presenting the content, was 3.75 and received a very good category. The average value obtained for the aspect of language is 4.00 and is in the very good category.

The evaluation aspect of the practicum tool laboratory manual presented in the form of a diagram can be seen in Figure 5.

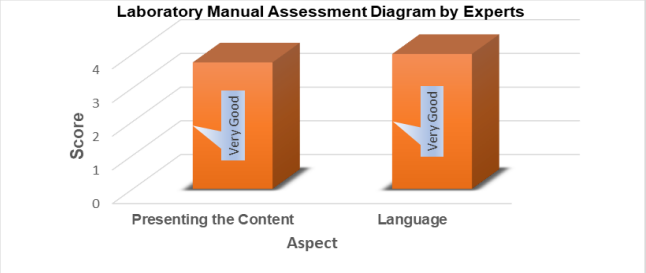

Figure 5. Laboratory Manual Assessment Diagram by Experts

Suggestions and criticisms from experts are adding explanations of usage procedures, using recognized references, and adding tables for manual tools.

Tool revision

Based on the suggestions and criticisms from material experts and media experts, a revision of the practicum tool for measuring temperature and humidity based on a microcontroller using telemetry was carried out. The suggestions used as a reference for improvement are in the laboratory manual, which is presented in more detail in the use of tools so that they are easy to understand. The physical appearance of the tool cannot be repaired because it uses a sensor, so if a cover is made, it will affect when the sensor detects/reads the temperature and humidity of the surrounding air.

B. Product Trials

a. Tool quality assessment by a physics teacher

Tool quality assessment by a physics teacher at State Senior High School 2 Palu with two teacher, State Senior High School 7 Palu with two teacher, and State Senior High School 9 Palu with two teacher.

Aspects of assessing the quality of practicum tools presented in diagram form can be seen in Figure 6.

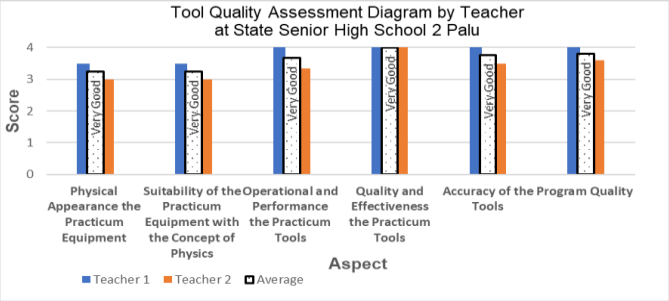

Figure 6. Tool Quality Assessment Diagram by Teacher at State Senior High School 2 Palu

Aspects assessed by experts include aspects of the physical appearance of practicum tools, aspects of compatibility of practicum tools with physics concepts, aspects of operation and performance of practicum tools, aspects of quality and effectiveness of practicum tools, aspects of tool accuracy, and aspects of program quality.

For the assessment average value by two teachers at State Senior High School 2 Palu, the results of the assessment of the physical appearance aspects of the practicum equipment are in the very good category with an average value of 3.25, the aspect of the suitability of the practicum equipment with the concept of physics is in the very good category with an average value of 3.25, the operational and performance aspects of the practicum tools are very good with an average value of 3.66, the quality and effectiveness aspects of the practicum tools are very good with an average value of 4.00, the accuracy of the tools is very good with an average score of 3.75, the aspect of program quality is in a very good category with an average score of 3.80.

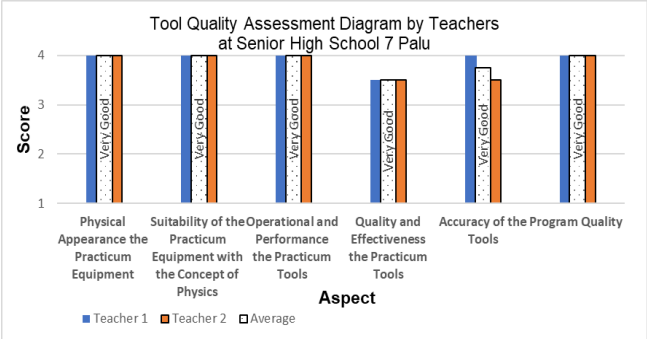

Figure 7. Tool Quality Assessment Diagram by Teachers at Senior High School 7 Palu

For the assessment average value by two teachers at State Senior High School 7 Palu, the results of the assessment of the physical appearance aspects of the practicum equipment are in very good category with an average value of 4.00, the aspect of the suitability of the practicum equipment with the concept of physics is in a very good category with an average value of 4.00, the operational and performance aspects of the practicum tools are very good with an average value of 4.00, the quality and effectiveness aspects of the practicum tools are very good with an average value of 3.50, the accuracy aspects of the tools are very good with an average score of 4.75, the aspect of program quality is in a very good category with an average score of 4.00.

For the assessment average value by two teachers at State Senior High School 9 Palu, the results of the assessment of the physical appearance aspects of the practicum equipment are in very good category with an average value of 3.50, the aspect of the suitability of the practicum equipment with the concept of physics is in a good category with an average value of 3.00, aspects of the operation and performance of practicum tools in the very good category with an average value of 3.83, the quality and effectiveness aspects of the practicum tools in the very good category with an average value of 3.25, the accuracy aspects of the tools in the very good category with an average score of 4.00, the aspect of program quality is very good category with an average score of 3.83.

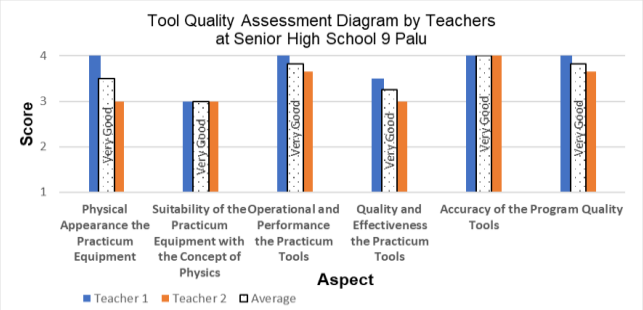

Figure 8. Tool Quality Assessment Diagram by Teachers at Senior High School 9 Palu

Suggestions from the assessment of the tool by the physics teacher are that this tool can be developed so that it can be used for IOS/PC and can not only measure air/room temperature. It is necessary to add a comparison of the explanations of the tools related to temperature. The use of tools that are easy to understand clearly by users with materials that are easy to obtain. The tool can be patented.

C. Assessment of the quality of laboratory manuals by physics teachers

Assessment of the quality of the laboratory manual by a physics teacher at State Senior High School 2 Palu with two teacher, State Senior High School 7 Palu with two teacher, and State Senior High School 9 Palu with two teacher.

Aspects assessed by experts physics teacher at State Senior High School 2 Palu include the content presented and the language used. Aspects of the manual assessment of laboratory tools offered in the form of diagrams can be seen in Figure 9.

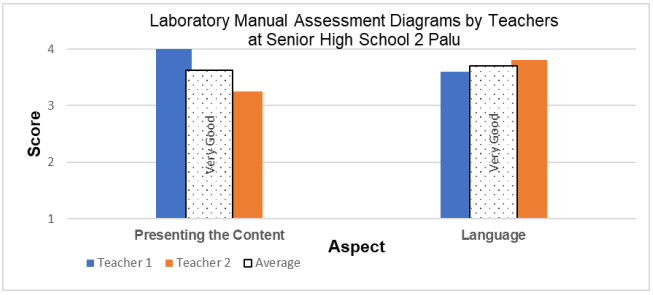

Figure 9. Laboratory Manual Assessment Diagrams by Teachers at Senior High School 2 Palu

The aspects assessed from the practicum laboratory manual include the content presented and the language. The assessment results of the average aspect for the teachers at Senior High School 2 Palu were that the content aspect was raised in a very good category with an average score of 3.62, and the language aspect was in a very good category with an average score of 3.70.

Aspects assessed by experts physics teacher at State Senior High School 7 Palu include the content presented and the language used. Aspects of the manual assessment of laboratory tools presented in diagram form can be seen in Figure 10.

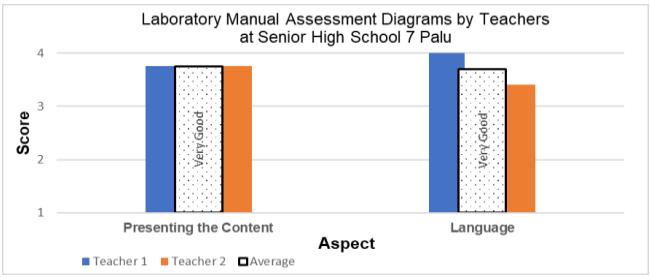

Figure 10. Laboratory Manual Assessment Diagrams by Teachers at Senior High School 7 Palu

The aspects assessed from the practicum laboratory manual include the content presented and the language. The assessment results of the average aspect for the teachers at Senior High School 7 Palu were that the content aspect was raised in a very good category with an average score of 4.75, and the language aspect was in a very good category with an average score of 3.70.

Aspects assessed by experts physics teacher at State Senior High School 9 Palu include the content presented and the language used. The evaluation aspect of the practicum tool laboratory manual presented in the form of a diagram can be seen in Figure 11.

The aspects assessed from the practicum laboratory manual include the content presented and the language. The assessment results of the average aspect for the teachers at Senior High School 9 Palu were that the content aspect was raised in a very good category with an average score of 3.62, and the language aspect was in a very good category with an average score of 3.30.

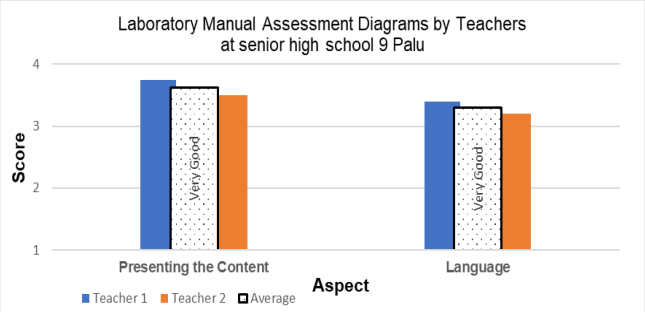

Figure 11. Laboratory Manual Assessment Diagrams by Teachers at Senior High School 9 Palu

D. Results of Responses to the Limited Test

Results of Responses to Practicum tools by Laboratory Assistants.

The results of the responses to the criteria for practicum tools by students consisted of five aspects, namely the physical appearance of practicum tools, in terms of the suitability of practicum tools with physics concepts, the operation and performance of practicum tools, the quality, and effectiveness of practicum tools and the output or results of practicum tools.

Students who give assessments here are physics laboratory assistants of the Teacher Training and Education faculty, totaling six people. As for the assessment results, that is, in the aspect of the physical appearance the practicum equipment, the average value obtained was 3.08 and received a good category. For parts of the suitability of the practicum equipment with the concept of physics, the value obtained is 3.5 and gets a very good category.

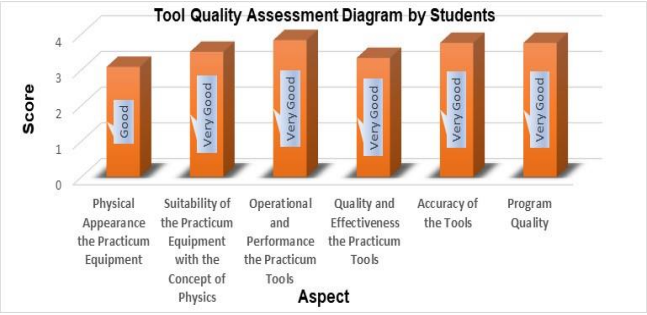

Figure 12. Tool Quality Assessment Diagram by Students

In the aspect of operational and performance the practicum tools, the value obtained is 3.83 and gets the very good category. In the aspect of quality and effectiveness the practicum tools, a score of 3.33 was obtained in the very good category. In the aspect of accuracy of the tools, it gets a value of 3.75 and is a very good category. In the aspect of program quality, it gets a value of 3.75 and is a very good category.

As for suggestions and criticisms from laboratory assistants, namely improving product quality, namely in the physical appearance of the tool so that a place is made to protect the components from external interference so that the tool is not easily damaged and looks more attractive.

Laboratory Manual Response Results By Laboratory Assistants

The results of the responses to the laboratory manual for measuring temperature and humidity based on a telemetry microcontroller consist of two aspects: the content presented and the language.

Laboratory assistant response results regarding the laboratory manual, namely, for the content aspect presented, the average value obtained was 3.62 and received a very good category. For the language aspect, the score obtained is 3.66, and is in the very good category.

Aspects of the manual assessment of laboratory tools presented in diagram form can be seen in Figure 13.

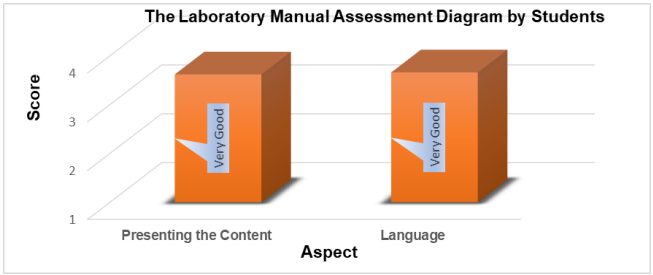

Figure 13. The Laboratory Manual Assessment Diagram by Students

Laboratory Test Results for Practicum tools

Table 6. laboratory test results

1. Using a telemetry-based microcontroller-based air temperature and humidity meter
   - Temperature/air temperature

Measured	Temperature	Conversion		
	(C)	K	F	R
Dry temperature	31°	304°	87,8°	24,8°
Wet temperature	32°	305,15°	89,6°	25,6°

- Humidity

Place	Temperature (°C)	Humidity Average (%)
Dry temperature	31°	81%
Wet temperature	32°	78%

2. Using manual/standard tools

- Temperature

Measured	Temperature (°C)	Conversion		
		K	F	R
Dry temperature	31°	304°	87,8°	24,8°
Wet temperature	32°	305,15°	89,6°	25,6°

- Humidity

Place	Temperature (°C)	Humidity Average (%)
Dry temperature	31°	81 %
Wet temperature	32°	78 %

Based on the results of laboratory tests for air temperature, the results obtained are very close to the literature. For air humidity, the values obtained are not far from the literature, so the tool made is feasible to use.

The results of the practicum tool development research are described based on the steps for developing a research model, which includes the stages of Preliminary Studies, Planning Research, data collection, product design, tool validation, tool revision, product trials, and the results of responses in limited trials.

Discussion

This research aims to develop digital tools for measuring air temperature and humidity, which can be monitored remotely (telemetry). The hope of researchers with the development of this tool is that it can help speed up the practicum process and master the concept of temperature and humidity [9]. With this tool, it is hoped that it can also become a reference to make something more technological, such as knowing programming languages and microcontroller systems [10] [11] [12] and [13].

The initial stage of developing this tool is making the product's initial design. Next, research the components that will be used to function as expected. The practicum tools are arranged according to the initial procedure when the details have been examined starting with designing the mechanical parts of the tool so that all sensors function correctly, such as how the PCB board shape will be used so that the circuit layout schematic works appropriately and how the sensor layout and other components work properly. This is done because the mechanical form of the tool to be significantly made influences the accuracy of the measuring instrument. If the mechanics have been made, the next step is to arrange the electronics; this stage also needs to be considered carefully so that the circuit layout schematic and the DHT11 sensor as a temperature and humidity meter can function correctly. How is the connection of the sensor with the HC-05 Bluetooth module and with the microcontroller used (arduino). After the practicum tools have been well structured, the next stage is programming. The programming language used here is the programming language for the Arduino application. Arduino is not just a development tool, but a combination of hardware, programming language and Integrated Development Environment (IDE) [14]. After doing the programming, the next step is to make an application to display temperature and humidity results on the cellphone screen. This application uses an inventor web app connected to a stable internet network. After the tool has been made, it is included in the quality assessment of the tool and laboratory manual, where this assessment uses a questionnaire that has been modified.

Based on the advice from the peers lecturer during the tool trial consultation, it is to pay more attention to the physical part of the tool so that it is not easily damaged due to unintentional external disturbances and to pay attention to the calibration of the tool using other comparison tools so that measurement results or errors can be known. From the results of experiments and calibration with manual/standard tools that are often used, values are obtained using a telemetry-based microcontroller temperature and humidity measuring device for a dry temperature of 31°C with 81% humidity value for a wet temperature of 32°C with humidity 78%. At the same time, using a manual/standard tool for a dry temperature of 31°C with a humidity of 39% value for a wet temperature of 32°C with a humidity of 42%. From the results obtained, it can be seen that the measurement using a microcontroller-based measuring instrument for temperature and humidity follows the manual tool for

temperature/temperature. However, for the air humidity measuring instrument, the value is still different because the measurement using this manual measuring tool produces an unstable value. So, measurements using a microcontroller-based temperature and humidity meter are more accurate and precise. This research is relevant to that conducted by [15]. It's just that in his research, observations or readings of the values are still displayed on the LCD screen. Whereas in the tools that the researcher has made observations or reading the values can be done by telemetry (remote) where the value display can be seen on the cellphone screen. After making repairs to the following tool, make a laboratory manual for the developed tool. The next stage is expert validation. The expert in this study was a Physics lecturer at the Teacher Training and Education Faculty of Tadulako University.

Assessment by experts is an assessment instrument to obtain feedback. What is assessed by the experts is the feasibility of practicum tools and the feasibility of laboratory manuals. The input given by media experts to improve product quality is on the physical part of the tool so that it is not easily damaged. Material expert input for the feasibility of the laboratory manual, namely adding an explanation of the procedure for using the tool, a recognized reference, and a table for the manual tool. The responses from material experts were used as a reference in product improvement, in this case, by conducting an initial revision of the laboratory manual. The physical appearance of the research tool has yet to improve because it uses a sensor, so if a cover is made, it will affect when the sensor detects/reads the temperature and humidity of the surrounding air. From the results of expert validation, an assessment of the tool is feasible to be tested in the field with revisions.

After being declared feasible by media and material experts and having made revisions, at this stage, it is included in the assessment, then proceed with a limited test. This limited test was carried out on a small scale with six physics laboratory assistants of the Teacher Training and Education Faculty of Tadulako University, 2 physics teachers from senior high school 2 Palu, 2 physics teachers from senior high school 7 Palu and 2 physics teachers from senior high school 9 Palu.

Based on the results of the questionnaire assessment, for positive statements, the average laboratory assistant strongly agreed, and for negative statements, the laboratory assistant didn't agree. From the results obtained, the effectiveness of a telemetry-based microcontroller-based air temperature and humidity meter provides convenience in carrying out practicum activities and is more interesting. While the efficiency of using this tool is the time needed is faster when compared to manual tools.

The advantage of this tool is that it is digital-based, and readings of measurement results can be monitored remotely (telemetry). Has an electronic circuit and microcontroller and streamlines time during practicum. This tool has limitations, namely on the physical appearance of the tool, which is easily exposed to unintentional interference from the outside.

The final product

The final product of the practicum tool for measuring air temperature and humidity based on a microcontroller by telemetry after expert assessment physics teacher and several physics education students of the Teacher Training and Education Faculty can be seen in Figure 14.

Figure 14. Final Product

CONLUSION

Based on the research and data analysis results, it can be concluded that: A practicum tool for measuring temperature and humidity based on a telemetry microcontroller has been made. Based on the assessment results from experts, physics teachers, and 6 Physics laboratory assistants at Teacher Training and Education of Tadulako University, the laboratory tools and manuals met the criteria very well, although there were still some weaknesses.

REFERENCE

[1] Wartono, *Pengembangan Program Pengajaran Fisika*. Mlaang: FMIPA UNM, 2003.

[2] F. Kreith and A. Prijono, "Prinsip-prinsip Perpindahan Panas, edisi ketiga," *Surabaya: Erlangga*, p. 13, 1997.

[3] R. Harisuryo, S. Sumardi, and B. Setiyono, "Sistem Pengukuran Data Suhu, Kelembaban, Dan Tekanan Udara Dengan Telemetri Berbasis Frekuensi Radio," *Transient J. Ilm. Tek. Elektro*, vol. 4, no. 3, pp. 651–659, 2015.

[4] F. Djuandi, "Pengenalan Arduino," *E-book. www. tobuku*, vol. 24, 2011.

[5] D. Sugiyono, "Metode penelitian pendidikan pendekatan kuantitatif, kualitatif dan R&D," 2013.

[6] M. Endang, "Riset terapan bidang pendidikan dan teknik," *Yogyakarta Andi*, 2011.

[7] D. Mardapi, *Penyusunan Tes Hasil Belajar*. Yogyakarta: PPs Universitas Negeri Yogyakarta, 2004.

[8] S. Arikunto, "Prosedur Penelitian Suatu Pendekatan Praktik, Jakarta: Rineka Cipta..(2013)," *Prosedur Penelit. Suatu Pendekatan Prakt. Ed. Revisi VI. Jakarta Rineka Cipta*, 2010.

[9] U. Pratiwi, "Kontrol suhu berbasis arduino dengan interface Matlab sebagai alat bantu praktikum fisika dasar," *J. Pendidik. Surya Edukasi*, vol. 2, no. 2, pp. 14–26, 2011.

[10] Jamzuri, "Pembuatan Sistem Akuisisi Data Pengukur Suhu Menggunakan Labview Interface For Arduino (LIFA)," *J. Mater. dan Pembelajaran Fis.*, vol. 6, no. 1, pp. 25–29, 2016.

[11] A. Permatasari, Y. Yuberti, and W. Anggraini, "Pengembangan lampu sensor berbasis Arduino uno sebagai alat peraga fisika," *Indones. J. Sci. Math. Educ.*, vol. 2, no. 3, pp. 380–387, 2019.

[12] M. Iqbal, Y. Yulkifli, and Y. Darvina, "Rancang Bangun Sistem Pengukuran Suhu Dan Kelembaban Udara Menggunakan Sensor Sht75 Berbasis Internet of Things Dengan Display Smartphone," *Berk. Fis.*, vol. 22, no. 3, pp. 97–104, 2019.

[13] S. Suherman, I. Andriyanto, and S. Dwiyatno, "Rancang Bangun Alat Ukur Temperatur Suhu Perangkat Server Menggunakan Sensor LM35 Bebasis SMS Gateway," *PROSISKO J. Pengemb. Ris. dan Obs. Sist. Komput.*, vol. 2, no. 1, 2015.

[14] M. Iqbal, "Pembuatan Sistem Pendeteksi Wajah Menggunakan Sensor Kamera Face Detector Berbasis Arduino Atmega328." Universitas Pendidikan Indonesia, 2012.

[15] H. Budianto and S. Winardi, "Rancang Bangun dan Web Monitoring Pengukur Temperatur Suhu untuk Peringatan pada Ruang Server Menggunakan Sensor DHT 11 dengan Modul Komunikasi Arduino Uno," *J. Univ. Narotama Surabaya*, 2012.