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DEVELOPMENT OF AN INTEGRATED MONITORING SYSTEM FOR TEMPERATURE, AIR HUMIDITY, SOIL MOISTURE, AND LIGHT INTENSITY IN MEASUREMENT AIDS IN SECONDARY SCHOOLS

RESEARCH ARTICLE

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Abstract
This study aims to evaluate instructional the feasibility media for physics learning, to describe students' responses to monitoring system media, and to assess students' learning outcomes after utilizing these media. The research method used is the Research and Development (R&D) method, using the ADDIE model, which includes five phases Analyze, Design, Development, Implementation, and Evaluation. The subjects of this study consisted of 36 students in class X at SMA N 06 Bengkulu City. Data collection tools used in this study are questionnaires and tests of students' concept understanding. Data analysis techniques using a Likert scale with a scale of four.The results of the analysis stage showed that 77.8% of students agreed with development of learning media that has been designed. Development stage resulted in a validation score of 87.5% from the evaluator, which was categorized as very feasible. The student response to the media showed a percentage of 80.3%. The post-test results showed an average score of 84.16, with an average percentage score of 84%, categorized as good. This conclusion aims to evaluate students' conceptual understanding and responses, showing that instructional media can help students' conceptual understanding.

Keywords: development, educational tools, measurement, monitoring system

Introduction

Learning is the process of acquiring knowledge, skills, attitudes, and values through experience, observation, or teaching. This process involves interaction between individuals with the environment and available information and requires motivation and desire to understand and apply what is learned. Learning can occur in a variety of contexts, both formal such as in schools and universities, as well as informal through everyday experiences. Learning methods vary, from traditional classroom learning to modern approaches that utilize digital technology, such as online courses and project-based learning. In addition, learning is also individual; Everyone has different learning styles, such as visual, auditory, or kinesthetic, which affect the way they absorb and process information. By understanding how to learn most effectively for themselves, individuals can improve their ability to learn more efficiently and enjoyably (Nasir, 2017). Among students, it is common knowledge that studying physics is a difficult subject to understand. The use of media in learning helps teachers to explain learning materials and also makes students more involved in the learning process. The use of teaching aids in learning activities can increase students' interest in the material taught (Pambudi et al., 2018).

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Physics is the science of nature. This refers to the word physics which comes from the Greek, namely fysikos which means "natural", and physics which means "nature". In the study of nature, physics studies the phenomena of non-living nature or matter within the scope of space and time. Physicists or physical scientists investigate the behavior and characteristics of matter in a very diverse area, ranging from the submicroscopic particles that make up all matter (particle physics) to the behavior of matter in the cosmos as a unified cosmos. Understanding concepts is a major aspect in physics learning because it can affect student learning outcomes. The concept itself is an abstraction that describes events, objects, or things that have similarities. In other words, concepts are the result of individual thinking about definitions, laws, and theories that have been taught, as conveyed by Nasir (2017).

Meanwhile, monitoring is the process of collecting data from resources, which generally includes real-time data. Monitoring systems serve to monitor activity on a device, with one of the main benefits being to detect potential problems in a contractor's system before damage occurs. In general, a monitoring system refers to the direct collection of information, which is done to observe data from measuring instruments, and can be done anytime and anywhere, as explained by Rangan et al. (2020). Temperature, in a qualitative context, is a measure that describes the state of being hot, cold, or warm in everyday conversation. Heat itself refers to energy that moves from one object to another. Temperature is a unit of heat intensity, not heat quality, as described by Friadi and Junadhi (2019). Air humidity indicates the amount of water vapor present in the atmosphere, which is the basis for the existence of water vapor. This water vapor comes from the evaporation process of water on the earth's surface, groundwater sources, and evaporation from plants. As an important part of the atmosphere, its presence is highly relevant in weather and climate studies, as expressed by Putra and Faiza (2022).

Meanwhile, soil moisture refers to the amount of water that fills pores of the soil on the surface. The other definition states that soil moisture is the water stored dynamically between soil particles, which is affected by evaporation on the soil surface, as described by Murasyd et al. (2022). In addition, light intensity is the amount of energy received by plants per unit area and per unit time, measured in cal/cm^2/day. The unit of light intensity used is the candela, symbolized I, while one lux is measured on a surface bounded by a steradian angle (Sugiarto et al., 2023).

According to research of Anggereni (2020), this study aims to look at science process skills and the appropriate use of digital thermometers for scientific process skills. The results of this study show that the average score shows the students' science process skills after using *thermometer* digital is 83.17. According to research by Lubis (2023), this study was conducted to determine the significant influence of the use of the Kinemaster-assisted inquiry learning model. The result of this study is that the use of the kinemaster-assisted inquiry learning model has a more significant impact on the conceptual understanding of high school students. According to research of Sintia et al. (2018) who designed and manufactured GSM SIM900A and arduino uno based soil moisture and air temperature monitoring tools. In this study, a DHT11 sensor and a soil moisture sensor were used, the results of this study were soil moisture and air temperature monitoring tools using GSM SIM900A and arduino uno which can calculate air temperature using a DHT11 sensor and soil moisture was measured using a sensor *soil moisture*.

The characteristics of students who sit in high school tend to have a low level of thinking ability and a simple mindset so they need to be guided gradually to improve their thinking skills. In daily life,

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students must be able to explore and master students understanding, understanding, and skills in solving problems in daily life. Given that critical thinking skills are essential for student learning, especially in physics studies, teachers should constantly check their students' thinking skills (Nuranisa et al., 2024). Based on previous research, many teaching aids have been used in physics education, but there are still few that have been developed using Arduino microcontrollers. As for those who have developed tools based on the Arduino Uno, none have combined the four variables that I developed. This development is expected to be one of the teaching tools that can attract students' attention to study physics.

The above research has explained that some of the learning media used in physics learning are still widely carried out in the form of direct measuring tools such as calipers, screw micrometers, *thermometer*, *lux* meters and so on. In this study, props will be developed using an arduino microcontroller assisted by a DHT22 sensor, a BH1750 sensor and a *soil moisture*. The three sensors will be assembled into props, with a DHT22 sensor that measures air temperature and humidity, a BH1750 sensor that measures light intensity, and a soil moisture sensor that measures soil moisture. The reason for using these three sensors is that their value readings are of better quality compared to other sensors. Later this tool will facilitate activities in terms of measurement.

There are problems that have been described above, therefore with an interest in developing teaching aids for measuring temperature, air humidity, soil moisture and light intensity made in one tool so that it can be easier in a measurement activity. This interest arises because in previous research, no one has used these four variables. The purpose of this study is to see the feasibility of monitoring system tools and to find out the students' response to the teaching aids after the tools are implemented in the learning of physics measurement materials. And to see students' understanding of the concept of measurement after the application of teaching aids. With this tool, it is hoped that later in physics learning not only use oral methods but also use practicum, and not only use practicum tools such as cheerleaders, thermometers and so on. So that students become more understanding of learning concepts and more interested in physics subjects.

Literature Review

This review topic explains important concepts related to teaching aids in physics learning, measurements, and monitoring systems to monitor environmental conditions with accuracy. Props support physics understanding, while measurements generate objective data. Monitoring systems collect real-time data on temperature, air humidity, soil moisture and light intensity. The importance of these conditions lies in physics experiments, photosynthesis, and soil fertility. Integrating various measurement tools in a monitoring system increases accuracy and effectiveness in research as well as education, making it an important topic for data-driven learning media development.

Props

Teaching aids are tools or objects used to assist teachers in delivering material to students, so that students can focus more on receiving lessons. Teaching aids are tools that can be accepted by the eyes and ears to help teachers conduct the teaching and student learning process more efficiently (Setiawan et al., 2022). Learning using props means optimizing students' five senses to increase

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learning efficiency by listening, seeing, touching and using logical and practical thinking. The lesson is not only about exploring the abstract world but also about concrete and practical experimental processes, as well as a part of life that is hard to forget. Teaching aids are very important in conveying learning so that it can be understood more clearly. However, props are not a substitute for oral lessons, but as a complement so that lessons can be remembered for a long time by students and are easily expressed when needed later (Wahyuni, 2022). Educational props can be more suitable for individuals, where students learn with the possibility of more than two people, so that the learning process becomes fun for each individual. Educational aids have the benefit of learning faster and quickly adapting between classes and outside the classroom, teaching aids allow teaching to be more organized (Afriani et al., 2022).

Measurement and monitoring system

Measurement is the act of systematically determining the value of an object. Measurement holds a crucial position in the development of science and technology and in the presentation of information (Nasution, 2019). In line with this opinion, Rasyid (2008) stated that "measurement is the process of giving numbers to certain attributes or characteristics possessed by certain individuals, objects, or objects based on clear rules or formulations. On the other hand, according to Arkundato (2008), Measurement is the process of evaluating a quantity, namely comparing the value of the measured quantity with other similar quantities.

A monitoring system is the process of collecting data from various sources. Generally, the data collected is real-time data (Fauzan et al., 2020). A monitoring system is a system that can be used to monitor the activities that occur on a device. One of the uses of the monitoring system is to be able to know in advance the state of the device in case of a problem (Arimi et al., 2023). A monitoring system is a data collection that is carried out in real-time to observe data from measuring instruments by humans anywhere and anytime (Rangan et al., 2020). Based on the explanation above, it can be concluded that a monitoring system is a systematic mechanism that monitors the activities of a process and data collection.

Temperature

Temperature is one of the important factors in recognizing changes in the condition of a substance or object. By observing temperature changes, physical changes can also be noticed. Therefore, it is very important to monitor the temperature of the desired object. In the health sector, temperature monitoring can be done with several methods to find out temperature changes, especially in humans. Temperature is a measure that indicates how hot or cold an object is. One of the tools used to measure temperature is a thermometer. In the past, temperature measurements relied more on the sense of touch. However, with technological advancements, thermometers were invented to measure temperature more accurately (Ardiyanto et al., 2021).

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Air humidity and Soil Moisture

Air humidity indicates the water vapor content in the air. This level of water vapor in the atmosphere actually contributes for only a small part of the entire atmosphere, ranging from 0% to 5% of the total air mass. This water vapor is an important component of the air from a weather and climate perspective. Air humidity is the amount of water vapor present in the atmosphere. Water vapor in the atmosphere is produced by the evaporation of water on the earth's surface, groundwater or water produced by the evaporation of plants, the instrument used to measure it is the hygrometer (Friadi & Junadhi, 2019).

Soil moisture refers to the quantity of water that fills part or all of the soil space above the groundwater level (water table). Another definition states that soil moisture is water that is stored dynamically between soil pores and is affected by the evaporation process at the soil surface (Murasyd, et al., 2022).

Light intensity

Light intensity refers to the amount of energy a plant receives per unit area per unit time (cal/cm^2/day). Therefore, the definition of intensity already includes the duration of exposure, which is the number of hours the sun shines per day. Basically, the intensity of sunlight has a significant impact on the morphological characteristics of plants, as the conversion of CO2 and water into carbohydrates requires the intensity of sunlight. Light intensity is a fundamental physical measure that evaluates the energy emitted by a light source in a given direction per unit angle. The SI unit of light intensity is the candela (Cd). From the description of light intensity, we can conclude that light intensity is the total amount of light received from a source in a given location (Supplement et al., 2023).

Methodology

Research design and approach of the study

The research methodology used is the Research and Development (R&D) method. According to Sugiyono (2012), research and development is a research method used to create products/tools and test the effectiveness of these products/tools (Marisa, 2021). Development research method or better known as Research and Development. This method is an approach used to make a specific product, as well as test the effectiveness of the product (Sati et al., 2023).

The ADDIE model stands for Analytics, Design, Development, Implementation and Evaluation. This model was selected because the ADDIE model phase reflects a systematic development approach and because the ADDIE model is widely used (Sugihartini & Yudiana, 2018). *Research and Development*. It is the process or steps to develop a new product or improve an existing product. Development research is a type of research that can serve as a link or bridge between basic research and applied research (Okpatrioka, 2023).

In the analysis phase, direct observations were made in the field, and a needs analysis questionnaire was used for the development of teaching aids. Meanwhile, in the design phase, the steps for creating block diagram designs and flowcharts of the monitoring system props were carried

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Volume 11| Number 2|Dec 2024|

out. In the development phase, the assembly of a series of tools from several sensors to be used with the help of Arduino Uno and validation of the tools by a team of validators were conducted. After the tools were validated, they could be implemented in physics learning in the classroom, followed by the distribution of a student response questionnaire regarding the teaching aids. Additionally, a test of students' understanding of the measurement concepts was conducted after using the teaching aids. The evaluation phase was carried out at each stage of the ADDIE model.

Research sites and participants

A sample is several characteristics that a population has, researchers can use samples taken from the population (Sugiyono, 2017). The research sample to develop a monitoring system for temperature, humidity, soil moisture and light intensity is 36 grade 10 students from SMA N 06 Bengkulu city. This research utilized both qualitative and quantitative data. Qualitative data was obtained from the recommendations submitted by the experts. Quantitative evaluation is determined from the results of questionnaires received and answered by students.

Prop feasibility analysis

The validation questionnaire was evaluated by this team of experts using the Likert scale with the criterion of "strongly disagree", "disagree", "agree", and "strongly agree" from this team of experts to obtain the percentage of product/tool validity with equation 1 below:

$$P = \frac{f}{N} \times 100\% \qquad (1)$$

Information:
P = Sum of Percentage Numbers
f = Score Obtained
N = Maximum Number of Scores (Sevtia et al., 2022).

The final score of the tool validation results by experts/validators has been carried out and the percentage value has been obtained, the next step can be to match the data from the tool validation calculation with category listed in table 1 below

Table 1. *Category for tool validation results*

Criterion	Percentage
Very Unworthy	0% - 25%
Not eligible	26% - 50%
Proper	51% - 75%
Highly Worthy	76% - 100%

Sugiyono (2015).

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Analysis of teaching aids needs

The material needs survey was distributed to grade 10 students. The purpose of this survey is to find out students' needs for educational resources to support their learning activities. The assessment of this needs questionnaire uses *the Likert Scale*. The formula used to calculate the results of the needs questionnaire is as follows in equation 2:

$$Percentage = \frac{\boldsymbol{average\ score}}{\boldsymbol{highest\ score}} \times 100\% \qquad (2)$$

The results of this needs questionnaire are then calculated until the final average score is obtained. After that, it is calculated using the equation mentioned earlier, until the final result is obtained from the percentage of data. The final results are then matched with a table of criteria to interpret the requirements questionnaire as shown in table 2 below:

Table 2. *Interpretation of the needs questionnaire*

Percentage	Groups
0% - 25%	Strongly disagree
26% - 50%	Disagree
51% -75%	Agree
76% - 100%	Strongly agree

Irwanto (2021).

Analysis of student response

Distribute response questionnaires to students after this questionnaire is distributed to find out responses from students regarding teaching aids that have been applied in learning. The data obtained from the student response questionnaire were processed using the formula in Equation 3 below:

$$Likert\ Scale = \frac{total\ score}{highest\ score \times number\ of\ questions \times number\ of\ students} \times 100\% \qquad (3)$$

The results obtained from this response questionnaire will later be calculated using the formula above by calculating the results on each aspect, until the final percentage score on each aspect and the average score of several aspects are obtained. The results obtained will be matched with the table of interpretation criteria contained in table 3 below:

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Volume 11| Number 2|Dec 2024|

Table 3. *Response questionnaire interpretation criteria*

Percentage	Group
85% ≤ RS	Very Positive
70% ≤ RS < 85%	Positive
50% ≤ RS < 70%	Less Positive
RS < 50%	Not Positive

Mardianto et al. (2022).

The results of the post test scores from the students' concept comprehension questions are then calculated for the average percentage score. Then matched with table 4 of the interpretation below:

Table 4. *Interpretation of concept understanding*

Value	Group
85,00 – 100	Superior
70 - 84,99	Good
55,00 - 69,99	Enough
40,00 - 54,99	Low
0,00 - 39,00	Very Low

Results

Data results

The results of the research on the development of an integrated monitoring system for temperature, air humidity, soil humidity and light intensity in teaching materials for measurement materials in high schools. This research applies the R and D approach and applied the ADDIE model which consists of several stages, namely analysis, design, development, implementation, and evaluation.

Analysis

The analysis stage is carried out to identify problems that exist in the physics learning process. Through direct observation at school, information was obtained that there are still many students who have difficulties in learning physics and also the low level of student curiosity about physics learning. The learning method used is still using the lecture method. The results of direct observation at school also found several other problems besides that, such as facilities and infrastructure that already exist in schools but have not been utilized optimally in physics learning. During the learning process, teachers still use a lot of teaching materials in the form of prints and have not used teaching aids in physics learning.

In this phase of analysis, the needs of teaching materials in physics classes are also analyzed. Based on the needs analysis questionnaire distributed to students, the results of the needs distributed

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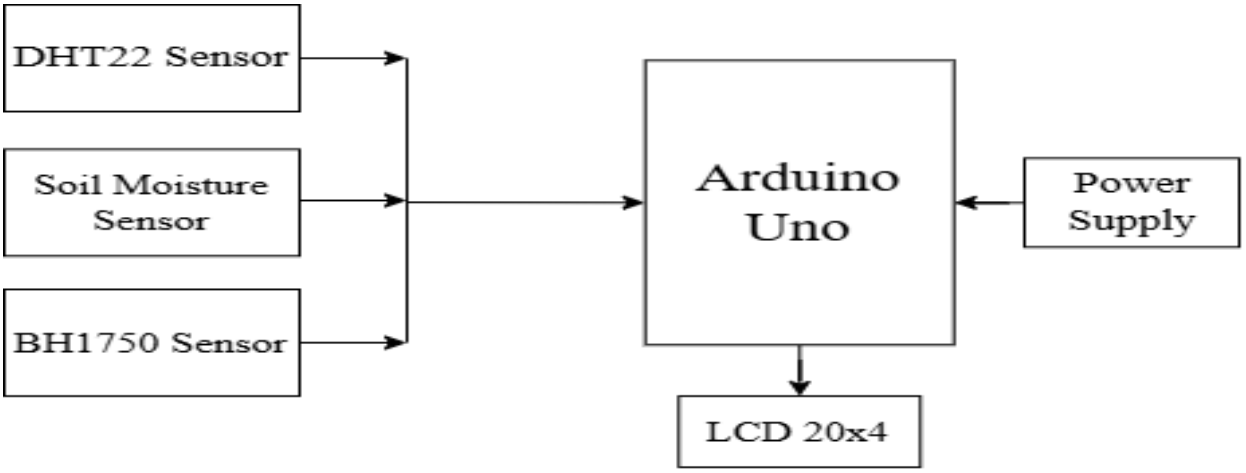
Volume 11| Number 2|Dec 2024|

to students show that students need physics teaching materials that they can observe and see directly. The results of the questionnaire distribution on the need for the development of teaching aids in measurement materials amounted to 77.8% who were included in the criteria were very agreeable. Based on the problems found through the results of observation and socialization of the needs questionnaire, it can be concluded that teaching aids are needed to help physics learning. The literature study showed the suitability of the findings of the problem with related research conducted by Utari (2022) concluded that the number of tools in the laboratory was limited and some tools did not function or were damaged, so it was necessary to develop tools.

Design

The next stage is the design stage, at this stage the design of the equipment to be used is carried out in this research begins. The equipment designed in this study is a system to measure temperature, air humidity, soil moisture, and light intensity. This equipment is designed to attract students' attention in learning physics. In the design stage, there are two designs to be made, namely hardware design and software design. This design stage also creates a diagram of the device block of the temperature, air humidity, soil moisture, and light intensity monitoring system as shown in figure 1 below. In the design of this device, three sensors will be used, namely the DHT22 sensor as a temperature and humidity sensor, the soil moisture sensor as a soil sensor, and the BH1750 sensor as a light intensity sensor. In addition to these three sensors, here the Arduino Uno is also used as a microcontroller or as a network brain, a 20x4 LCD that is useful as a data viewer generated by the three sensors and processed by the Arduino, and then the data from the Arduino is sent to a 20x4 LCD so that it can be read.

Figure 1. *Monitoring system tool block diagram*



This solid stage in addition to making a block diagram from the monitoring system tool, also makes a flow design or workflow diagram of the monitoring system tool as depicted in the flow diagram in Figure 2.

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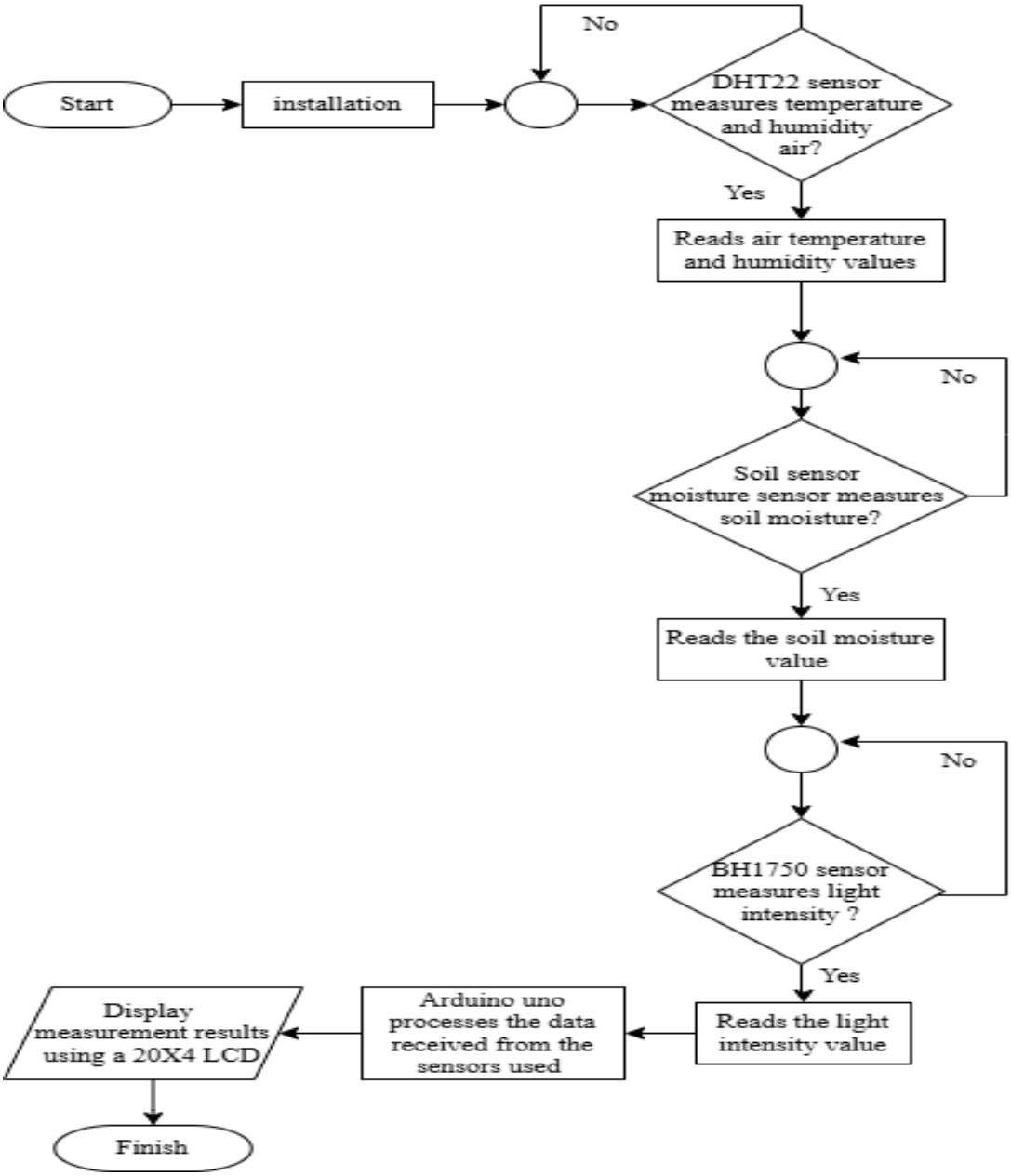
Volume 11| Number 2|Dec 2024|

Figure 2. *Flowchart monitoring system*



Development

The third stage is the development stage or development. At this stage, the design of the system tool is carried out Monitoring starting from hardware and software. The first is for sensors that will use the help of three sensors, namely the DHT22 sensor, the BH1750 sensor and soil moisture sensor.

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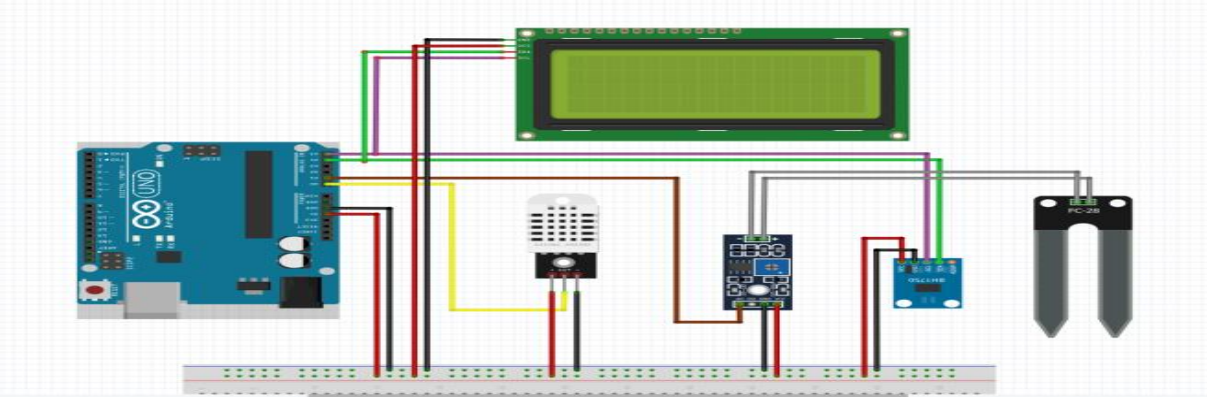
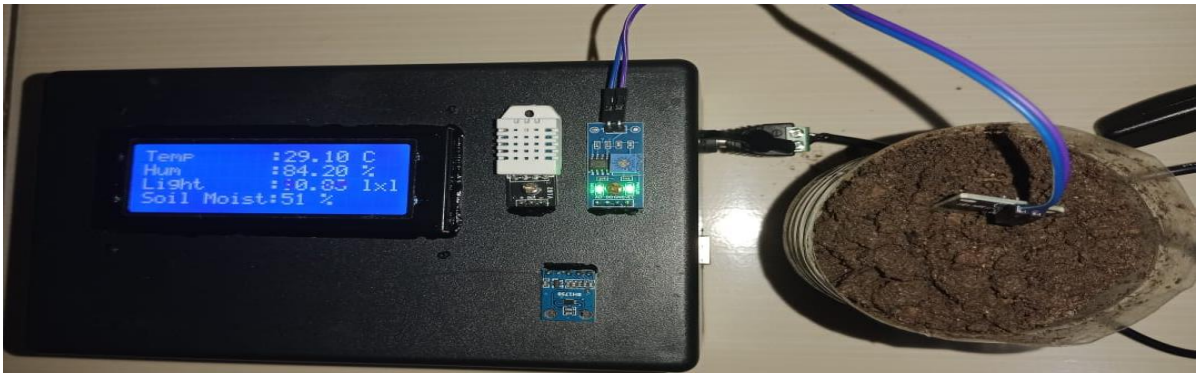
Next, hardware integration is done by connecting all the sensors with the arduino microcontroller as shown in Figure 3. The software development on the arduino IDE, after completing the coding, will be transferred to the previous circuit. And to display the measurement results with the tool will be visible on the LCD used in the tool series. The device will later be tested directly to various environmental conditions repeatedly, the test results of this device show that the system of measuring temperature, air humidity, soil humidity and light intensity is working well.

Figure 3. *Monitoring system toolkit*



After the assembly of the tool is completed according to the design that has been created, the next step is to submit the pre-made coding using the arduino IDE. And the shape of the finishing tool will look like in figure 4 below.

Figure 4. *Monitoring system tools*



Tool validation is carried out by three validators which is intended to determine the feasibility of system tool Monitoring temperature, air humidity, soil moisture, and light intensity. The validation results by the validators state that the tool is very feasible to use, with the validation results by each validator as shown in table 5 below:

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Volume 11| Number 2|Dec 2024|

Table 5. *Interpretation results of tool validation*

Assessment Indicators	Percentage (%)			
	Validator I	Validator II	Validator III	Middle
Tool Essentials	75	91,66	100	88,88
Relevance of the tool to the material	75	75	87,5	79,16
Embracing the value of education	75	75	75	75
Tool durability	87,5	87,5	87,5	87,5
Aesthetic	87,5	87,5	100	91,66
Technician components	85,71	85,71	92,85	88,09
salvation	100	100	100	100

Based on the table, it shows that the score obtained from validator I is 83.3%, validator II is 86.1%, and validator III is 93.05%. So, the average value obtained from the three expert validators is 87.5%, where the value can be categorized as very decent. With the percentage of each aspect, namely the essence aspect of the tool 88.8% with a very feasible category, the aspect of the relationship between the tool and the material 79.1% with a very feasible category, the aspect containing educational value 75% with the feasible category, the durability aspect of the tool 87.5% with very feasible criteria, the aesthetic aspect 91.6% with very feasible criteria, the technician component aspect 88.0% with very feasible criteria, and the safety aspect is 100% with very feasible criteria. It can be concluded that the tools of temperature, air humidity, soil moisture, and light intensity monitoring systems are categorized as very feasible to use, although there are some suggestions and inputs for the tools developed. As for the advice from the validator to pay attention to the unit in each variable result measured, pay more attention to the light intensity sensor measurement results because it is still fluctuating, and the delay in the change time in the results is still very fast.

Implementation

The fourth stage is the implementation stage or Implementation. Once the tool has been validated by the validator team and the tool has been declared feasible for use with some suggestions from the validators, the tool can be used for implementation. At this stage, the application of system tools is carried out Monitoring Temperature, air humidity, soil moisture and light intensity as teaching tools on measurement material in class X senior high school. During the process of applying the tool to high school grade X students, students pay attention during the explanation of the system tool Monitoring. Students are also very enthusiastic about the use of monitoring system tools and students also practice the use of tools directly, in the implementation activities students also ask about the function of monitoring system tools in physics learning. At this implementation stage, the researcher also provided a student response questionnaire which aimed to observe student responses to the monitoring system tools that had been developed.

The results of students' responses to temperature, humidity, soil moisture, and light intensity monitoring tools were obtained from student response questionnaires. Below, the results of the students' responses are shown in Table 6.:

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Volume 11| Number 2|Dec 2024|

Table 6. *Student response results*

Assessment Indicators	Total score	Percentage	Average Percentage	Group
Motivation and Learning Concept	816	81%	80,3%	Positive
Operation of the appliance	342	79%		
Prop Qualification	467	81%		

Based on the results of student responses in Table 8 above, the evaluation results for each aspect are displayed. In terms of motivation and learning concepts, 81%, in terms of equipment operation, 79%, and in terms of the feasibility of teaching materials, 81%. The overall average percentage obtained from these three aspects is 80.3%, and according to the interpretation table the students' responses are in the range of 70% ≦ 85% < 85%, so the evaluation is in the positive category. The hospital is there. This shows that the teaching tools of the temperature, humidity, soil moisture, and light intensity monitoring system bring students the joy of learning physics.

After asking students to complete the Student Response Survey, the next step is to ask them to complete the measurement conceptual comprehension test questions that have been prepared. The results of the students' conceptual comprehension test are shown in Table 7 below.

Table 7. *Results of students' understanding of the concept*

Value range	Group	Frequency	Percentage
85,00 - 100	Superior	16	44%
70 – 84,99	Good	20	56%
55,00 – 69,99	Enough	-	-
40,00 – 54,99	Low	-	-
0,00 – 39,99	Very Low	-	-
Sum		36	100%

Based on table 9 of the results of students' understanding of the concepts above, students who obtained scores with very good category of 16 students with a proportion of 44% of 36 students, students who got a score with a good category of 56% as many as 20 students out of 36 students. The average score obtained was 84% with a good category.

Evaluation

The evaluation phase is the final step of the ADDIE development phase. This evaluation activity was carried out based on the results of verification of the results, student reactions, and the opinions and suggestions of experts. Evaluation can also be divided into two parts: formative and summative evaluation. This development uses a phoemic evaluation, which is included in each step or phase of ADDIE.

Formative evaluation is carried out based on observation and needs analysis questionnaires. Based on the results of the observations made, it was found that there were still a shortage of teaching

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ISSN |2355-3669| E-ISSN |2503-2518|
Volume 11| Number 2|Dec 2024|

materials and there are still several learning places that do not use teaching materials to help students understand the concept. Therefore, it is necessary to develop educational tools to help students learn physics. The results of the needs survey revealed that 77.8%. From these results, it can be concluded that students need the development of teaching aids. Evaluation at the design stage is a change in the monitoring flowchart system. Evaluation at the development stage is a change in the type of soil moisture sensor part. From the results of the validation of the tool by the validator, it is evaluated in terms of the essence of the tool, the relationship between the tool and the material, educational value, durability of the tool, aesthetics, technical components, and safety. The average percentage is 88.42%, and the validity level of the criteria shows that this criterion is very precise. Suggestions and opinions to improve the system tools to monitor This is also requested. Formative evaluation at the implementation stage is a questionnaire with student answers. According to the results of the questionnaire with the students' answers, all students responded positively to the temperature, humidity, soil moisture, and light intensity monitoring system tools, and the average percentage score was 80.3%, which was included in the positive category.

Discussion

Tool needs analysis

The use of the ADDIE development model demonstrates a high degree of flexibility with a common structured framework for developing instructional interventions (Safitri and Aziz, 2022). Based on the results of the needs analysis conducted in grade 10 of SMA N 06 Bengkulu City, it was shown that the percentage of teaching material needs in the category "Full agreement on the development of teaching materials for physics teaching" was shown. Based on the results of the questionnaire calculation, there is one question with the lowest score. In the question "Teacher does physics internship in school laboratory", students answer that they do not agree with the question. Many students stated that they had never done an internship in a material measurement laboratory. In this needs analysis, the opinion that the presence of teaching materials will make understanding teaching materials easier and the learning environment more comfortable was also obtained from many students, and they agreed with the development of teaching materials in the field of measurement teaching materials. This is in line with previous research (Kumalasari et al., 2023) which states that it is important to develop teaching aids to help implement physics learning.

Tool eligibility

From the data from the validation of the teaching aids of the monitoring system temperature, air humidity, soil humidity and light intensity by the validator, suitable categories for use and with constructive suggestions were obtained. With the percentage results of each aspect listed in table 7 which states that the developed tool has the essence value of the tool which is included in the very feasible criteria with the statement that the tool is easy to use, easy to assemble and the tool is accurate in measurement. In terms of the relevance of the tool to the material, a very feasible criterion is given, with the statement that the tool is needed in learning, the teaching aids are clear and related to learning. In the aspect of containing educational values is also included in the feasible category, in this aspect it

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ISSN |2355-3669| E-ISSN |2503-2518|
Volume 11| Number 2|Dec 2024|

gets the lowest percentage of the other seven aspects. This is estimated because the measurement results are displayed in English in writing and not everyone knows the components used. Similarly, the aesthetic value of the developed tool states that the tool is very attractive and the components of the tool are neatly arranged. In terms of components, the technicians also got a very high score, where the tool was declared very decent. Meanwhile, the security *apk* is declared very feasible, which means the tool is perfectly safe for middle school students to wear. Based on the average results of the three validators, the devices that have been validated are can be categorized as very feasible, it can be concluded that the tool is feasible to use. According to previous research Rasyid et al. (2023) With the result of tool validation of 94.1% which shows that the monitoring system tool is suitable for use.

Student responses to teaching aids

Based on student response data obtained from student response questionnaires, positive criteria were obtained, which means that students responded positively to the application of system tools Monitoring Temperature, air humidity, soil humidity and light intensity to physics learning. With the value of each aspect listed in table 8 of the results of the student response. From the results of the three aspects assessed, the results of the operation of the tool are slightly lower than the other two aspects. This happens due to a lack of knowledge about the microcontrollers used and students still find it difficult to distinguish the results listed on the LCD using English, which still sounds unfamiliar to students' knowledge. These results are in line with previous research (Sya'roni et al., 2021) which stated that the students' response to Arduino-based teaching aids obtained a score above 80%, which was also actively asked by students during learning and student activities in using teaching aids. The results obtained from the students' concept comprehension test sheets with an average score of 36 students were 84.16. The percentage of students' average score in understanding the concept of measurement is 84% with a good category, which can be interpreted that the level of student understanding of measurement material is good.

Conclusion and Implications

The analysis stage was carried out to analyze the needs of class X students for teaching aids on measuring materials, by showing results that strongly agreed with the development of teaching aids on measuring materials. The results of the needs analysis showed that the percentage was 77.8% with the criteria of strongly agreeing. The developed temperature, air humidity, soil humidity and light intensity monitoring system tools show the results of the validation of the tool which is very feasible and usable. With the validation results of each validator are 83.3%, 86% and 93.05%, and the average result of the three validators is 87.5% with very feasible tool criteria. Then based on the results of the student responses that have been carried out, it shows positive results on the development of a monitoring system for temperature, air humidity, soil humidity and light intensity that are integrated in the teaching aids in this measurement material. With a student response of 80.3% with the category of positive student response to the development of monitoring system tools. Furthermore, based on the results of the evaluation that has been carried out after the application of equipment to class X students, the average score of 36 students is 84.16. The results of the average score of the student's concept comprehension test, if the percentage, reaches 84% by having good criteria, it can be

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Volume 11| Number 2|Dec 2024|

interpreted that the tools developed can help students understand concepts in physics learning. A suggestion is to choose a portable and functional power source so that it can be used anywhere without difficulty in finding an energy source. In addition, the results displayed on the LCD need further attention to ensure that the information conveyed is clear and easily understood by students. This will help students better understand the data displayed and support an efficient learning process.

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