Physics Communication
Volume 9 Issue 1 Year 2025 Pages 7-18

P-ISSN 2528-5971 | E-ISSN 2528-598X
https://journal.unnes.ac.id/journals/pc
https://doi.org/10.15294/pc.v9i1.4461

Development of Arduino UNO-based Heat Practicum Tool with LM35 Sensor to Improve Student Graphic Interpretation

Mufid Eska Nurcahya*, Sarwi, Teguh Darsono

Master of Physics Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia

*Correspondence to: *mufideska@students.unnes.ac.id*

Abstract: Technology is the result of the process of scientific development. 21st century technology has developed rapidly in the scope of education. High-level thinking is an important competency for students in the 21st century. For this reason, learning planning is needed that is able to improve high-level thinking competencies, especially in terms of student interpretation. Many practical lessons at SMA N 1 Balapulang are still not technology-based. This research aims to produce a practical tool based on Arduino UNO to improve graphic interpretation for high school students. This type of research is Research and Development (R & D) and uses a research model, namely ADDIE (Analysis, Design, Development, Implementation, Evaluation). Based on validation by tool experts, it was found that the practical tool media developed received a score of 92.5% in the very good category. The characteristics of the media developed are the Arduino UNO microcontroller with an LM35 sensor to read the temperature of the liquid being measured, the interface of the Arduino UNO is PLX-DAQ software so that it is stored in MS Excel, there is a LKPD developed to make it easier for students during practicum. The results of improving student graphic interpretation seen from the pre-test and post-test obtained an average score from 57.11% to 89.61%. The N-Gain value obtained was 0.72, where there was an increase in graphic interpretation for students in the high category. The results of the analysis of heat change calculations proportional to temperature changes can improve student interpretation of graphs.

Keywords: Arduino UNO; Graphic interpretation; LM35; Physics practical tools; PLX-DAQ

Submitted: 2024-11-03. **Revised:** 2025-02-16. **Accepted:** 2025-02-19.

Introduction

Indonesia This century can be called the century of knowledge, a knowledge-based economy, the century of technology, globalization, and the century of industrial revolution 4.0 (Redhana, 2019). 21st century technology has developed rapidly and rapidly within the scope of education. Technology is the result of the process of scientific development in the world (Lestari, 2018). The development of 21st century skills should be able to improve interpreting, logical thinking, analyzing and creative skills (Darmaji et al., 2018; Sarwi et al., 2019). Like today's education, technology is also utilized to help carry out the learning process. Learning in the 21st century must be able to prepare generations of students in Indonesia to welcome the progress and development of information and communication technology in social life (Syahputra, 2019). The use of technology in the world of education has the aim of ensuring that the results obtained in the educational process can continue to progress, being able to develop and create something new (Hana and Subali, 2023). One use of technology in the learning process in schools is to help teachers carry out their duties, such as as a medium and learning resource. Therefore, the use of technology in schools can create various kinds of learning models that can increase students' enthusiasm for learning (Mukaromah, 2020).

The teacher is a professional educator with the main task of educating, teaching, directing and evaluating students using various learning models and teachers have strategies for developing learning in the classroom (Sarwi et al., 2017; Darsono et al., 2021). Education cannot be separated from the existence of a learning model. Physics learning has various learning models that can be used by teachers to achieve the goals of teaching and learning activities. The teaching and learning process is a process that cannot be separated. Through an appropriate learning process, students are expected to be able to understand and master teaching material so that it can be useful in everyday life (Abdullah, 2017; Zahidah et al., 2023). Teaching and learning activities can be said to be a process of change from something that is not good to something that is better, such as changes in behavior, interest in learning, enthusiasm for learning, skills, attitudes and so on. The learning model is a series of structured processes so that effective knowledge transfer can occur between teachers and students (Khoerunnisa and Aqwal, 2020).

The learning process cannot be separated from the problems students face when understanding the material. Learning difficulties are one of the difficulties characterized by interference in understanding and analyzing the concepts of subject matter (Widia et al., 2022). Some behaviors are caused by difficulties in understanding the material, such as taking a long time to complete assignments, cheating on exams, skipping lessons, and so on. The habit of students only memorizing physics formulas without understanding the concepts will hinder students in learning physics, because physics is not just about memorizing but understanding of basic concepts must also be honed (Nurmasinta, 2021).

One of the subjects that students consider difficult is physics, where some students need extra thinking to be able to learn and understand it, resulting in some students at school experiencing learning difficulties (Ady and Warliani, 2022). Physics learning contains both concrete and abstract physics concepts, making it difficult for students to understand the material (Rahmi et al., 2022). According to Azizah et al., (2015), the difficulty of temperature and heat material is 26%, optical material is 25%, static fluid is 21%, elasticity and Hooke's Law is 17%, and kinematics is 11%, so students have difficulty understanding the material topic of temperature and heat. The method that is often used when learning is the lecture or one-way method, so that many students do not understand the material well (Sulandri, 2020).

Researchers made observations on Monday, September 12 2022 in the physics laboratory at SMA N 1 Balapulang, where there were only conventional practical tools and did not utilize technology. One of the practical tools for temperature and heat is a practical tool that only uses an analog thermometer hung on a stand. Students still record practical data manually by handwriting and calculating time using a stopwatch. Apart from that, the students said that they did not know the difference between temperature and heat, did not know how to calculate heat changes, and could not read graphs of temperature changes over time. In an effort to reduce students' difficulties in understanding temperature and heat material, interesting learning methods are used so that students are interested and easy to understand, so that the learning that takes place is not monotonous and students do not get bored easily.

Physics material is not all explained verbally but requires proper visualization, for example using visual aids (Alvian et al., 2017; Laksmana, 2023). The learning process using the practicum method has the advantage that students can have their own understanding and graphic interpretation of the practicum results. According to Charli et al., (2018), students experience difficulties in reading, understanding and making graphs because students lack knowledge and explanations in working on graph questions so that students still make mistakes when reading graphs. Interpretation is an activity of translating, interpreting, explaining the substance of a policy in language that is more operational and easy to understand. Interpretation carried out by students can explain a graph, data, text table or image. Interpretation skills are one of the most important skills in the current era of knowledge and technology, one of which is in physics (Wahyuningsih et al., 2021). Graphic interpretation is part of the representation that shows conceptual understanding by students (Yustiandi and Saepuzaman, 2017). Therefore, the process of students interpreting something in the learning process needs to be done so that students can understand the material conceptually.

Student interpretations can be obtained from the results of analyzing graphs, tables, images and symbols (Lindasari, 2020). One software that can display tables and graphs is the Parallax Data Acquisition tool (PLX-DAQ). Parallax Data Acquisition tool (PLX-DAQ) is software that is used to support experimental data storage, once installed it is automatically included in Microsoft Excel and is used as a graphic visualization so that you can interpret experimental data. The PLX-DAQ application is used to display and store data in Microsoft Excel (Yultrisna et al., 2021). This data acquisition software is quite easy for students to use so they can interpret the practicum results. PLX-DAQ is downloaded for free via the internet with the software size not being too large so it can be easily accessed. Using PLX-DAQ can make it easier to calculate and record data from the Arduino UNO directly and at a time that has been set according to needs. Manually recording data in practicums takes a long time and is inefficient because it requires students to monitor an analog thermometer along with a stopwatch and record the data results (Faldian et al., 2018). Therefore, the PLX-DAQ software is able to support and assist the learning model used, especially the temperature and heat practical learning model.

Practical learning in physics is a very important learning process to support students in higher level thinking (HOTS) where there are students' interpretation abilities. Physics practical learning on temperature and heat material, students are required to be able to interpret the results of the practical process in the form of graphs, data or tables. Physics practicum regarding temperature and heat contains data on changes in temperature over time where students can analyze the results of graph readings. The temperature and heat practicum at SMA N 1 Balapulang is still carried out conventionally, so that in order to be in line with 21st century developments, it is necessary to develop technology-based practicums. According to Azhar et al., (2022), analog measuring instruments cause difficulties for practitioners because the data obtained is inaccurate and practitioners make errors in reading measurement results. The use of an Arduino UNO microcontroller connected to a laptop in laboratory practicums can turn an initially conventional laboratory into a laboratory that follows developments in the 21st century and improves graphic interpretation in reading practicum results.

Based on the background above, it is necessary to carry out research on developing a temperature and heat practical tool based on Arduino UNO with an LM35 sensor to improve graphic interpretation for students. This research is expected to provide information about innovations in physics practicum that are able to improve students' high-level thinking abilities (HOTS), especially in graphic interpretation abilities. The novelty of this research is the improvement in student interpretation of graphs obtained from the results of technology-based temperature and heat practicum process analysis.

Methods

This research was conducted at SMA Negeri 1 Balapulang, Tegal Regency in class XI MIPA. The method used in this thesis research is the development method. The Research and Development (R&D) method is a research method to produce certain product results and test the effectiveness of the product. R&D is a research method used to produce a new product or product from development and test the effectiveness of the method during research used in learning (Hanafi, 2017; Herdiana et al., 2023). In this thesis research, the research model uses ADDIE (Analysis, Design, Development, Implementation, Evaluation) which was developed by Reiser and Mollenda (1990s) which is a generic learning design model that serves as a guide in building learning tools that are effective, dynamic and support performance. The ADDIE model shows the basic stages of a learning system design that is simple and easy to learn (Jaladri and Nursulistiyo, 2020). The ADDIE model has several stages:

Analysis

The analysis stage is a process for analyzing what is at issue in the learning process. The problem in learning is that the use of practical tools in the laboratory at SMA N 1 Balapulang has not yet integrated technology. Students carry out temperature and heat practicums still using manual methods by recording the time and temperature obtained and then analyzing them manually. Manually recording data can cause practical errors in recording data results, so there needs to be development to help reduce errors in reading and collecting data in practicums.

Design

The design stage is a very important stage for designing practical experimental tools, because good planning produces accurate practical tools. There are two design stages:

a. Determine tools and materials

In this research, the tools used are easy to obtain, easy for users to use and not too expensive. Based on the design of the measuring instrument in Figure 3.1, there are several components, including: LM35 sensor, Arduino UNO, Arduino IDE software, PLX-DAQ software, water, static kit, 12V heating element, measuring cup, laptop, burnt insulation, jumper cables, acrylic casing. Arduino UNO, and power supply.

b. Determine the tool set

The circuit in the Arduino UNO is an LM35 sensor with Pin A0 as well as Vin and GND, then connected to a laptop that has PLX-DAQ installed.

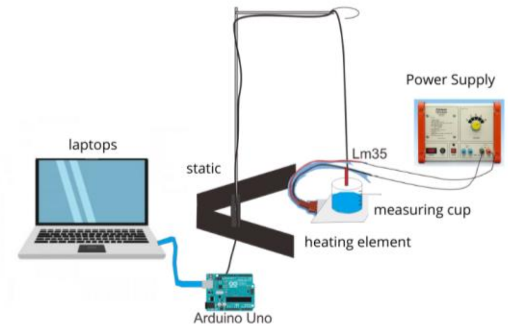


Figure 1. Design of experimental design

Development

The development stage is the stage of carrying out activities, namely creating and designing tools that have been designed. In this research, the practical tools that have been created are then validated by supervisors and product expert lecturers. At this stage a guidebook was also created for carrying out temperature and heat practicums. The aim of making a guidebook is so that the practical tools developed can be used by students easily.

Implementation

Implementation is an activity to test tools in practicum for students. After students carry out the practicum together, students are given a questionnaire to find out the students' interpretation of the practicum that has been carried out. Implementation was carried out at SMA N 1 Balapulang for class XI MIPA students. The aim of this implementation is so that the practical tools developed and the guidebooks developed can be used in physics practicum at SMA N 1 Balapulang.

Evaluation

The evaluation stage is an activity to assess the steps in each activity and whether the product results are in accordance with what is required. At this stage, an assessment and revision of the practicum tools is carried out. If there is an evaluation, the tools will be repaired.

Table 1. Pre-test post-test control group design

Subject	*Pre-test*	*Treatment*	*Post-test*
Class XI MIPA students	O_1	X	O_2

Improvement in student interpretation can be seen by comparing the conditions before and after treatment. This design can be described like in Table 1 (Sugiyono, 2015). Before being given treatment, students get a pre-test and after being given treatment, students get a post-test. The pre-test and post-test are questions about student interpretation in understanding concepts.

Results and Discussion

The research carried out is development research using the ADDIE model. The implementation of research into the development of temperature and heat practicum tools included pre-test, practicum and post-test stages which were carried out over four days starting from May 26 - May 31 2023. The research subjects were class XI MIPA-1 students with a total of 36 students. The location of the research was at SMA Negeri 1 Balapulang which is located at Jalan Banjaranyar, Balapulang District, Tegal Regency. The products developed in the research are practical tools and practical modules based on Arduino UNO using LM35 with a scientific approach to temperature and heat materials.

After going through the process of developing practical tools and developing student worksheets, data collection for students was carried out for 4 days. Each meeting has one pre-test day, two practicum days carried out by several groups which have been divided into 4 groups on the first day and 3 groups on the second day, and the last day is used for the post-test.

Validation of practical tools

Practical tools and LKPD (Learner Worksheets) for student practicum have been developed and validated by two experts, consisting of researchers (lecturers) and practitioners (teachers) through filling in validation sheets. Tool validation is carried out by tool expert lecturers or supervisors as a reference that the tool being developed is good and can be tested on students. Practical tool validation obtained a total score of 37 with a percentage of 92.5%, so the results of practical tool validation were in the very good category. The results of the validation of the feasibility of the practicum tools can be seen in Table 2.

Table 2. Validation results of practical tools by tool experts

No.	Question	Validator Score
Components used in tool development		
1.	Practical tools use simple and not too many components	4
2.	Practical tools have components that are easy to use	4
Practical equipment construction		
3.	The appearance of the practicum tools is attractive because they are integrated with technology	3
4.	Practical tools are portable, making them easy to store and carry	4
5.	Practical tools have an appropriate/balanced size	4
Use of tools		
6.	Practical tools can be operated easily	4
7.	The function of each component part of the tool does not confuse the user	4
Working steps of the heat change practical tool		
8.	The use of practical tools does not confuse users	3
Accuracy of measurement results of heat change practical tools		
9.	The LM35 sensor measurements are in accordance with/close to the thermocouple	3
10.	The results of the practical equipment readings can be used to measure changes in temperature and heat	4
Amount		**37**

Tool development and calibration

The practical tools developed are tools in the form of a series. The Arduino UNO is equipped with an additional acrylic protective box to protect the Arduino UNO from splashes of water or oil to avoid short circuits. Further development of the LM35 sensor involves wrapping it in epoxy with a thickness of less than 1 mm so that it is resistant to water but remains sensitive to temperature changes. A heating element with a voltage of 12V AC with a maximum power of 50W is used as a more stable heat source than a Bunsen heat source. The heating element voltage source is obtained from the power supply. Next, the data read in the PLX-DAQ software is displayed in Excel and can be saved.

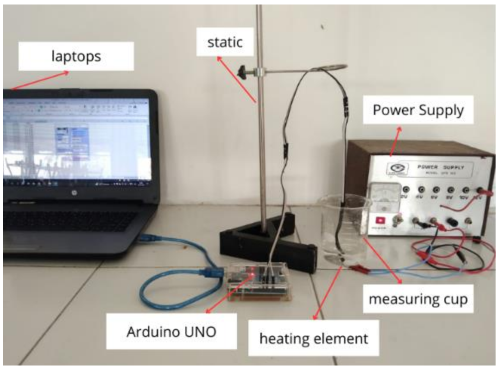


Figure 2. Results of developing temperature and heat practical tools

The LM35 sensor has a voltage reading. Every change in voltage on the LM35 is followed by a change in temperature so that the LM35 sensor and temperature thermometer can be compared. The graph of the increase in LM35 sensor voltage in proportion to the increase in thermometer temperature changes can be seen in Figure 3.

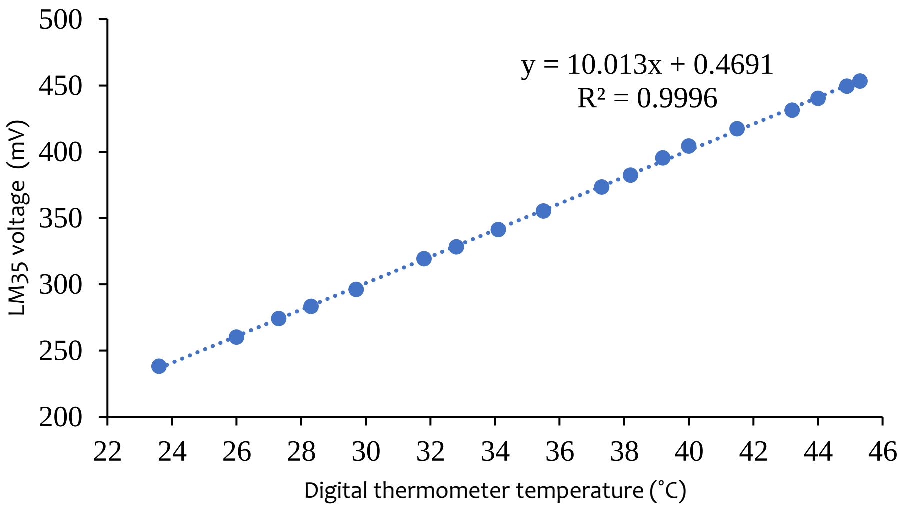


Figure 3. Graph of the increase in LM35 sensor voltage is proportional to the increase in temperature changes

The LM35 sensor in the temperature and heat practical tool that has been developed has been calibrated using a thermocouple. Calibration was carried out in the Master of Physics Education laboratory at Ahmad Dahlan University. Calibration is carried out by placing the LM35 sensor and thermocouple in a container containing ice cubes and adding 100 ml of water every five minutes. The temperature comparison results from the LM35 sensor voltage calculation and thermocouple readings can be seen in Figure 4.

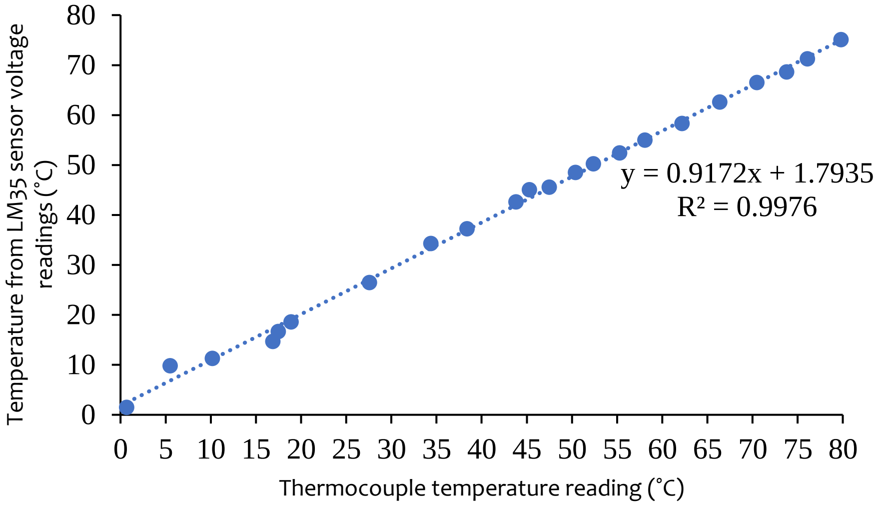
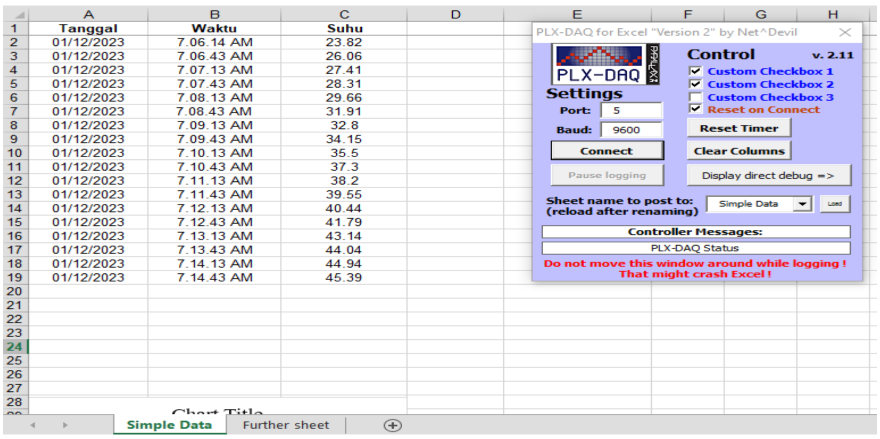


Figure 4. Temperature comparison graph from voltage calculations on the LM35 sensor and temperature readings on the thermocouple

Based on the graph above, the data was taken up to a temperature of 80˚C because after that temperature it was no longer linear so a linear result was obtained of T = 0.9172x + 1.7935 where T is the temperature read after calibration and x is the reading temperature of the LM35 sensor. The linear data results are entered into the Arduino IDE program so that the temperature calculation from the LM35 sensor can be close to the thermocouple temperature.

Development of calibrated temperature and heat practicum tools that can be used and applied in physics practicum. The use of practical tools connected to the laptop using the Arduino UNO USB port cable so that Ms. Excel that already contains PLX-DAQ can be opened and automatically display the PLX-DAQ software. The Arduino IDE software needs to be opened in order to read the Arduino UNO. The Arduino UNO which is connected to a laptop can be connected to the PLX-DAQ by matching the USB port settings used by the Arduino UNO. The programmed Arduino UNO can be connected to the PLX-DAQ in Excel by clicking the connect button so that the PLX-DAQ automatically reads the LM35 sensor displayed in the Excel column as in Figure 5.



Tanggal	Waktu	Suhu
01/12/2023	7.06.14 AM	23.82
01/12/2023	7.06.43 AM	26.06
01/12/2023	7.07.13 AM	27.41
01/12/2023	7.07.43 AM	28.31
01/12/2023	7.08.13 AM	29.66
01/12/2023	7.08.43 AM	31.91
01/12/2023	7.09.13 AM	32.8
01/12/2023	7.09.43 AM	34.15
01/12/2023	7.10.13 AM	35.5
01/12/2023	7.10.43 AM	37.3
01/12/2023	7.11.13 AM	38.2
01/12/2023	7.11.43 AM	39.55
01/12/2023	7.12.13 AM	40.44
01/12/2023	7.12.43 AM	41.79
01/12/2023	7.13.13 AM	43.14
01/12/2023	7.13.43 AM	44.04
01/12/2023	7.14.13 AM	44.94
01/12/2023	7.14.43 AM	45.39

Figure 5. Display of temperature reading results in table form from PLX-DAQ software in Microsoft Excel

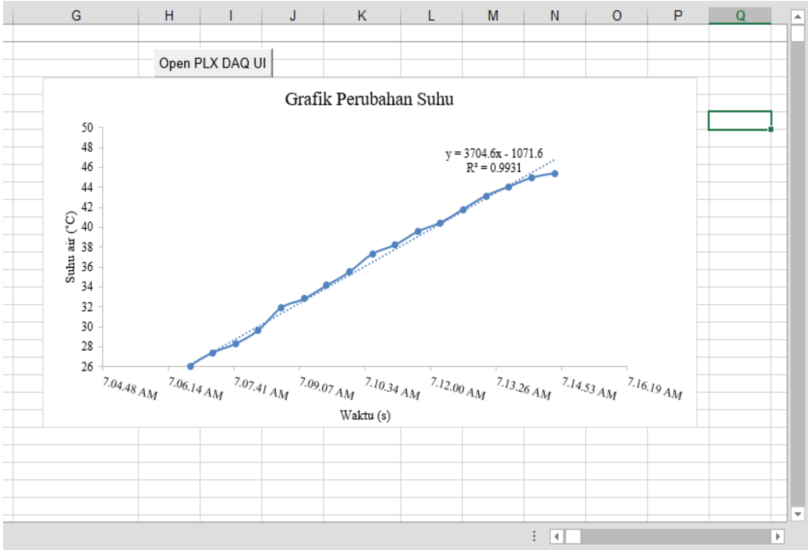


Figure 6. Display of temperature reading results in graphic form from PLX-DAQ software in Microsoft Excel

Figure 6. shows the results of reading the date, time and temperature according to the Arduno UNO program. Microsoft Ecxel can also display graphical results of temperature changes over time obtained from data in the Excel column in Figure 4.6. The results of temperature readings over time can be analyzed to prove that the heat change is proportional to the temperature change.

Development of LKPD

The practicum group consists of seven groups with five to six groups in each group. The first day of practicum was carried out by group one to group four and the second day of practicum was carried out by group five to group seven. Practicum starts at 08.00 WIB with an estimate for each group carrying out practicum for 90 minutes. During the practicum, each student is given a practicum LKPD as a guide to the temperature and heat practicum procedures. The students' practical LKPD can be seen in Figure 7.

In the LKPD given to students in Figure 7. (a) there are basic competencies, practicum objectives, tools and materials. In Figure 7. (b) and (c) there are pictures of the materials and their functions to make it easier for students to understand the practicum. In Figure 7. (d) there is an experimental procedure as a guide for students in carrying out practical steps, in Figure 7. (e) there are practical results to record data acquisition. In Figure 7. (f) there is a conclusion. The basic competencies in the LKPD are in accordance with the Syllabus and RPP for learning physics on temperature and heat. The tools and materials display pictures along with their function or use to make it easier for students to understand the practicum. In the observation results there is a table that students can fill in according to the data and observations in the practicum.

Student interpretation rubric for the category of understanding meaning

The implementation of technology integrated practicum using Arduino UNO was carried out in the Physics laboratory of SMA N 1 Balapulang on 26 May – 31 May 2023 when students had carried out the final semester assessment involving 36 students from class XI MIPA-1. The practicum is carried out in groups and alternately with other groups for two days. One day before the practicum, students were given a pre-test first to determine the level of graphic interpretation in students, then the next day after the practicum was carried out, students were given another post-test to determine the improvement in graphic interpretation in students. Based on the interpretation assessment rubric in Table 3. with a total of 10 questions, each question has a maximum score of 5 so the total score is 50.

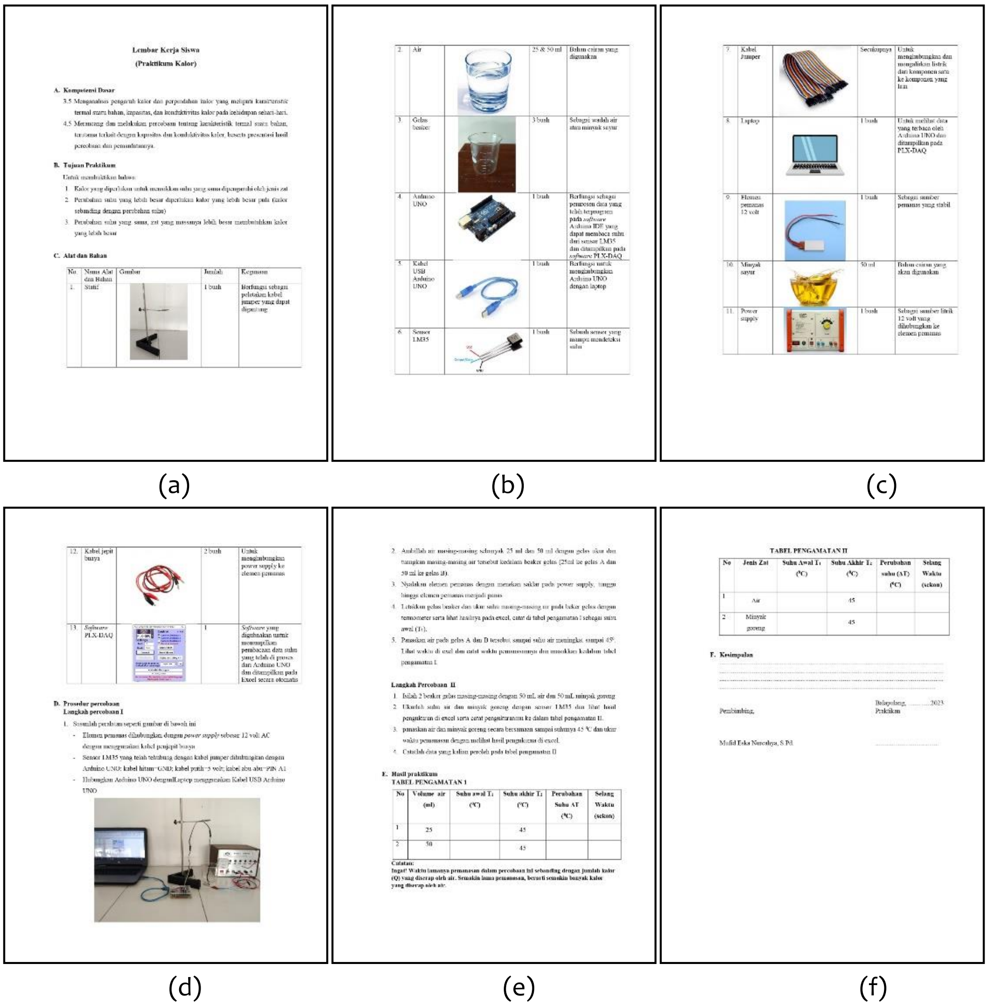


Figure 7. Technology integrated temperature and heat practical worksheet

Table 3. Student Interpretation Question Rubric from Test Of Graphing in Science (TOGS)

No.	Ability	Definition	Question items
1.	Identify graphs and data	Describe data in graphical form	1, 2
2.	Determine the independent variable data and the dependent variable into the graph	Selection of independent variable and dependent variable data in graphical form	3,4
3.	Determines the data value of the variable range	Selection of values from a variable data range	5
4.	Determining the variable name at coordinates (X,Y)	Mention the name of the variable at coordinates (X,Y)	6
5.	Determine data (X,Y) on the graph	Data on the x and y axes shown by the graph	7
6.	Explains data between phases on a graph	Interpolation on graphs	8
7.	Determines the extrapolation of the data in phases on the graph	Extrapolation on the graph	9
8.	Determine the relationship between variables on the graph	Relationship between independent variables and dependent variables	10

(Mustain, 2018).

Assessment of graphic interpretation questions from TOGS uses a 1-5 Likert scale which is used to measure students' level of interpretation. The Likert scale table can be seen in Table 4.

Table 4. Pre-test and post-test assessment scores

Category	Score
Very good	5
Good	4
Currently	3
Not enough	2
Very less	1

Table 5. Pre-test and post-test score results for students' level of graphic interpretation

	Lowest score	Highest score	Maximum score	Average score	Percentage of comprehension proficiency level (%)
Pre-test	19	43	50	28,56	57,11
Post-test	35	49	50	44,81	89,61

N-Gain test and Wilcoxon test

To determine the increase in the level of graphic interpretation in students, it can be analyzed using the N-Gain test from the results of the pre-test and post-test. The N-Gain test is used to determine the difference between the pre-test and post-test to determine the improvement after the practicum (Nuha et al., 2021). The results of the analysis obtained the lowest score, highest score, average score, percentage of average score which can be seen in Table 5.

The percentage results of the average score for the interpretation level assessment increased from 57.11% to 89.61%. The results of the analysis using SPSS analysis version 25 obtained an N-Gain value of 0.72, where there was an increase in graphic interpretation for students in the high category.

The Wilcoxon test was carried out to determine the differences between 2 paired samples. Based on the data obtained above, the result of a significance value <0.05 can be stated as having a difference in the means of two paired samples. This means that the level of students' ability to interpret graphs before and after the practicum can be obtained from the comparison results of the pre-test and post-test which have increased changes related to the level of graphic interpretation among students in the category of understanding the meaning.

Conclusion

The development of practical tools produces temperature and heat measuring devices using Arduino UNO and LM35 microcontrollers which have been calibrated with a thermocouple. Adding an acrylic board to the Arduino UNO as a protector and a place to place the sensor was then developed on the LM35 by protecting the sensor using epoxy to make it resistant to water. Use of heating elements as a heat source. The voltage source is obtained from the power supply. Furthermore, the data read by the PLX-DAQ software can be displayed and can be saved in Microsoft Excel.

The results of the validity of the learning tools, namely practical tools and LKPD, were validated by tool expert lecturers with a total score of 37 and a percentage of 92.5%. Validation of practical tools in the very good category so they are suitable for use. The results of the assessment of the practicum tool media were in the very good category so that it was suitable for use in temperature and heat practicum for class XI MIPA.

The average score of the pre-test and post-test assessment of the level of graphic interpretation among students increased from 57.11% to 89.61%. Analysis of the N-Gain Test results from the pre-test and post-test using SPSS version 25 analysis obtained an N-Gain Test of 0.72 where there was an increase in graphic interpretation for students in the high category. The difference between 2 paired samples using the Wilcoxon test obtained a significance result of 0.00, therefore the significance value was <0.05, so it could be stated that there was a difference in the level of students' interpretation abilities during the pre-test and post-test.

Acknowledgement

The author would like to thank the Principal of SMA N 1 Balapulang who has provided a place for research. We would also like to express our thanks to all parties who have directly or indirectly helped in completing this research and article.

References

Abdullah. (2017). Pendekatan dan Model Pembelajaran yang Mengaktifkan Siswa. *Edureligia*, *01*(01), 45–62. http://doi.org/10.33650/edureligia.v1i2.45

Ady, W. N., & Warliani, R. (2022). Analisis Kesulitan Belajar Siswa SMA terhadap Mata Pelajaran Fisika pada Materi Gerak Lurus Beraturan. *Jurnal Pendidikan Dan Ilmu Fisika*, *2*(1), 104–108. https:/doi.org/10.52434/jpif.v2i1.1599

Alvian, Yulianto, A., & Subali, B. (2017). Desain Alat Peraga Digital Image Creator For Optical Microscope (DIGICOM) dalam Pembelajaran IPA untuk Menumbuhkan Motivasi Belajar Siswa. *Unnes Physics Education Journal*, *6*(3).DOI: https://doi.org/10.15294/upej.v6i3.19312

Azhar, Melita, A. S., Doyan, A., Susilawati, Ayub, S., & Hudha, L. S. (2022). Digital Calorimeter for Measuring the Specific Heat of Liquids. *Jurnal of Physucs: Conference Series*, 1–7. https://doi.org/10.1088/1742-7596/2165/1/012034.

Azizah, R., Yuliati, L., & Latifah, E. (2015). Kesulitan Pemecahan Masalah Fisika pada SMA. *Jurnal Penelitian Fisika Dan Aplikasinya (JPFA)*, *5*(2), 44–50. https://doi.org/10.26740/jpfa.v5n2.p44-50

Charli, L., Amin, A., & Agustina, D. (2018). Kesulitan Siswa dalam Menyelesaikan Soal Fisika pada Materi Suhu dan Kalor di Kelas X SMA Ar-Risalah Lubuklinggau Tahun Pelajaran 2016/2017. *JOEAI (Journal of Education and Instruction)*, *1*(1), 42–50. https:/doi.org/10.31539/joeai.v1i1.239

Darmaji, Kurniawan, D. A., & Lestari, A. (2018). Deskripsi Keterampilan Proses Sains Mahasiswa Pendidikan Fisika pada Praktikum Suhu dan Kalor. *JRKPF UAD*, *5*(2), 68–72. https:/doi.org/10.12928/jrkpf.v5i2.10735

Darsono, T., Aji, M. P., Rusilowati, A., & Marwoto, P. (2021). Identifikasi Pemahaman dan Kemampuan Penulisan Artikel Ilmiah Berbasis PTK Guru SMA Kota Pekalongan. *Jurnal Panjar: Pengabdian Bidang Pembelajaran*, *3*(2), 42–46. https:/doi.org/10.15294/panjar.v3i2.52977

Faldian, Wallid, I., & Cahyana, Y. (2018). Monitoring Temperatur Sistem AC Split dengan Metode Akuisisi Data Berbasis Arduino Uno. *Prosiding Nasional Rekayasa Teknologi Industri Dan Informasi XIII*, *November*, 259–266.

Hana, F. S., & Subali, B. (2023). Pengembangan Lembar Kerja Siswa (LKS) Digital Berbasis STEM (Science, Technology, Engineering and Mathematics) untuk meningkatkan Penguasaan Konsep dan Kreativitas Siswa. *Unnes Physics Education Journal*, *12*(1), 42–49. https://doi.org/10.15294/upej.v12i1.67460

Hanafi. (2017). Konsep Penelitian R&D Dalam Bidang Pendidikan. *Saintifika Islamica: Jurnal Kajian Keislaman*, *4*(2), 129–150.

Herdiana, R., Aripin, & Mahmudah, I. R. (2023). Development Of Physics Props For Arduino Uno-Based Light Wavelength Gauges With Diffraction Lattice Method (Case Study of Visible Light Wavelengths). *Jurnal Pembelajaran Fisika*, *10*(2), 229–245. https:/doi.org/10.23960/jpf.v10.n2.202207

Jaladri, E. A., & Nursulistiyo, E. (2020). Development of Physical Practicum Tools to Determine the Refractive Index Through Measurement of Real Depth and Spparent Depth. *International Conference on Science Education and Technology*, 1–6. https://doi.org/10.1088/1742-6596/1511/1/012077.

Khoerunnisa, P., & Aqwal, S. M. (2020). Analisis Model-Model Pembelajaran. *FOndatia: Jurnal Pendidikan Dasar*, *4*(1), 1–27. https://doi.org/10.36088/fondatia.v4i1.441

Laksmana, N. (2023). Penerapan Model Pembelajaran Multidimensional pada Pembelajaran Fisika Pokok Bahasan Tekanan dalam Rangka Meningkatkan Keterampilan Proses Sains Siswa di SMP 1 Wedarijaksa Kabupaten Pati. *Unnes Physics Education Journal*, *12*(1), 86–90.

https:/doi.org/10.15294/upej.v12i1.66143

Lestari, S. (2018). Peran Teknologi dalam Pendidikan di Era Globalisasi. *Edureligia*, 2(2), 94–100. https://doi.org/10.33650/edureligia.v2i2.459

Lindasari, E. N. (2020). Pengaruh Penerapan Model Pembelajaran Inkuiri Terhadap Kemampuan Interpretasi dan Analisis Siswa Kelas IV SD Joannes BOSCO Yogyakarta. In *Repository USD*. Universitas Sanata Sharma. http://repository.usd.ac.id/id/eprint/36784

Mukaromah, E. (2020). Pemanfaatan Teknologi Informasi dan Komunikasi dalam Meningkatkan Gairah Belajar Siswa. *IJEMAR Indonesian Journal of Education Management & Administration Review*, 4(1), 179–185. https://doi.org/10.47668/edusaintek.v11i2.1167

Nurmasinta. (2021). *Analisis Kesulitan Belajar Fisika Peserta Didik pada Materi Hukum Newton*. Universitas Muhammadiyah Makasar. https:/doi.org/10.26877/jp2f.v15i1.14990

Rahmi, M., Syukri, M., Khaldun, I., Artika, W., & Huda, I. (2022). Development of a Virtual Lab in Science-Physics Learning Based on the STEM Approach. *Jurnal Penelitian Pendidikan IPA*, 8(4), 2057–2061. https://doi.org/10.29303/jppipa.v8i4.1660

Redhana, I. W. (2019). Mengembangkan Keterampilan Abad Ke-21 dalam Pembelajaran Kimia. *Jurnal Inovasi Pendidikan Kimia*, *13*(1), 2239–2253. https://doi.org/10.15294/jipk.v13i1.17824

Sarwi, S., Ellianawati, E., & Suliyanah. (2019). Grounding physics and its learning for building global wisdom in the 21st century. *Journal of Physics: Conf. Series 1171*. https://doi.org/10.1088/1742-6596/1171/1/012001

Sarwi, S., Kupardi, K. I., & Linuwih, S. (2017). Physics Structure Analysis of Parallel Waves Concept of Physics Teacher Candidate. *Journal of Physics: Conf. Series 824*. https:/doi.org/10.1088/1742-6596/755/1/011001

Sugiyono, P. D. (2015). *Metode Penelitian Pendidikan* (21st ed.). ALFABETA.

Sulandri. (2020). Analisis terhadap Metoda Pembelajaran Klasikal dan Metoda Pembelajaran E-Learning di Lingkungan Badiklat KEMHAN. *Jurnal Pendidikan Indonesia*, 1(2), 176–187. https://doi.org/10.36418/japendi.v1i2.16

Syahputra, E. (2019). Pembelajaran Abad 21 dan Penerapannya di Indonesia. *Prosiding Seminar Nasional SINASTEKMAPAN*, *1*, 1276–1283. DOI: https:/doi.org/10.31004/basicedu.v6i2.2082

Wahyuningsih, A. P. V, Maslebu, G., & Setiawan, A. (2021). Wireless bluetooth-based SIPESUT (Model Temperature Monitoring System) prototype. *Journal of Science and Science Education*, 5(1), 44–51. https://doi.org/10.24246/josse.v5i1p44-51

Widia, S., Zahriah, & Rusydi. (2022). Analisis Kesulitan Belajar Fisika Peserta Didik dalam Pembelajaran Daring di SMAN 4 Wira. *Jurnal Pendidikan Fisika Dan Terapan*, *3*(1), 22–27. DOI: http://doi.org/10.22373/p-jpft.v7i1.11944

Yultrisna, Irmansyah, M., Yuliza, M., & Junaldi. (2021). Manutech : Jurnal Teknologi Manufaktur Rancang Bangun Timbangan Buah Digital Berbasis Mikrokontroler Dengan Koneksi Printer Thermal. *Manutech : Jurnal Teknologi Manufaktur*, *13*(02), 97–104. DOI: https://doi.org/10.33504/manutech.v13i02.182

Yustiandi, & Saepuzaman, D. (2017). Profil Kemampuan Interpretasi Grafik Kinematika SiswaSMA Kelas X. *Gravity: Jurnal Ilmiah Penelitian Dan Pembelajaran Fisika*, *3*(1), 30–39. https:/doi.org/10.30870/gravity.v3i1.2410

Zahidah, N., Ellianawati, & Susilo. (2023). Analisis Respon Siswa Terhadap Penggunaan Media Mobile Learning Berbasis pada Materi Momentum dan Impuls. *Unnes Physics Education Journal*, *12*(1), 91–95. DOI: https://doi.org/10.15294/upej.v12i1.66145