Preparation of Future Teachers for Measuring Technical Quantities

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Abstract

In addition to acquiring pedagogical and methodological competencies, preparing future teachers of scientific subjects is also focused on acquiring practical skills of students from various technical fields. One of these fields is the measurement of technical quantities. The paper presents the methodological basics necessary for the preparation and implementation of environmental temperature measurement and the results of the measurements obtained by the students. Two thermometers were used to measure the temperature. The classical thermometer measured the air temperature, and a spherical thermometer measured the radiation temperature of the same environment. The obtained data were evaluated using methods of descriptive statistics, and the whole experiment was also assessed from the point of view of measurement methodology. The data obtained from the measurements of both thermometers showed differences, allowing the students to understand the difference between air and radiant temperatures.

Keywords: Measurement methodology, Didactics of scientific subjects, Temperature measurement

1 Introduction

Practical work, including laboratory work, has been part of science education for more than a century and is considered essential in teaching science and technical subjects. In his research, author Tetsuo Isozaki (2017) concluded that practical work (including laboratory work) should be considered a way to achieve a conclusion – not a conclusion. In this case, sufficiently educated teachers in science and pedagogy act as facilitators who support students in

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learning. Without enthusiastic teachers, using high-quality equipment fully and designed laboratory measurements are impossible. Thus, when doing practical work, the emphasis should be on its purpose and what students can learn from the experience – not just on the activities they perform while doing such work. This idea is also confirmed by the author Yap, who expressed that vocational education and training require integrating knowledge with practical skills (Yap et al., 2022). It is also necessary for students to engage in scientific research as part of laboratory work and for teachers to guide them to search for solutions, design experiments, formulate hypotheses, observe, organise data and provide explanations.

One of the goals of the laboratory teaching of Physics (as well as other science and technical fields) is to help students connect theory with practice. Experiments are often chosen to “demonstrate” particular concepts. Students are expected to approach phenomena scientifically, so they should develop a hypothesis and plan their experiments accordingly. Although it is not usually explicitly stated, these learning objectives require students to have conceptual knowledge before experimenting. Otherwise, they could not connect theory with practice or develop a hypothesis. Empirical evidence from process studies of university students' laboratory activities suggests that students rarely express their conceptual knowledge during practical work. Instead, experiments appear to be how students discover and “stabilise” conceptual understanding in learning Physics (Aufschnaiter, C. & Aufschnaiter, p.9, 2007).

Students' laboratory work is also one of the effective methods of teaching creative thinking. It is an essential process in learning science and technical subjects because students tend to have difficulty understanding basic concepts if they are only taught verbally. Students will gain a better understanding of the subject matter when they are given real-life examples, and at the same time, they can learn these concepts through laboratory work. Khoiri et al. conducted research that measured students' creative thinking skills. Creative thinking skills were measured based on four indicators: flexibility, fluency, originality and detail. Research results show that laboratory work improved students' fluency and thinking skills (77% of students showed improvement). It was also suitable for improving students' original thinking, with 84% of students improving (Khoiri et al., 2017).

We see that practical measurements of students have an outstanding contribution to the learning of students as well as to the development of their creative thinking. For students of technical fields, they are also an essential part of acquiring competencies in the field of working with measuring devices. Students at technical schools must know what measurements are performed on different types of mechanisms and how to do them. Teachers can use either analogue measuring devices or modern digital devices. Research done by several authors shows that older devices for measuring technical quantities are more beneficial for students not only for understanding the principle of measurement but also for understanding the structure of the measuring device (Macko et al., 2019).

Laboratories have been an essential part of academic education for a long time. However, the requirements for physical, chemical, and technical education have changed. However, while seminars and lectures are easily updated and adapted to new knowledge, modernised courses focused on work in the laboratory or practical measurements are much more complex: simple content changes require new expensive equipment, and strict course schemes do not allow for significant structural changes (Neumann, K., & Welzel, M., 2007). Therefore, the innovation of laboratory exercises for students greatly benefits every scientific field.

2 Choice of Measurement and Measuring Devices

In this article, we will show how it is possible to implement practical activities focusing on measuring technical quantities in the selected study program. The practical measurement was prepared for students and future teachers of Technology. The Teaching of Technology study program is a program of the second level of university education. By completing it, students receive the title of "master" (Mgr.). It follows on from the Bachelor's study program Teaching Practical Training. The full-time study is two years; in the external form, it is three years. Graduates of this study program will acquire deep theoretical knowledge about the fundamental factors and processes of socialisation and education, the cultural context of anthropogenesis and its psychological interpretations. They master the contents of general education and the contents of the disciplines of their specialisation, and the principles of their structure. They are familiar with the methodology of the field and its broader cultural and social contexts. They can handle this content as a product of human (scientific) activity, and in this context, they can project it for didactic purposes. During their studies, students acquire adequate knowledge of the organisation and management of education and research and development methods in pedagogy.

While preparing for their future profession, students of Teaching Technology need to acquire the necessary competencies in pedagogy and departmental didactics and necessary skills in practical activities such as laboratory or technical measurements. They can acquire these competencies only if they design and implement measurements themselves under the guidance of a teacher during their undergraduate training. Therefore, when preparing future teachers, guiding students to carry out such activities with their students in pedagogical practice is necessary.

First, choosing a suitable practical task is necessary, a measurement for which the student must prepare accordingly. Such preparation mainly consists of mastering the theory necessary for practical measurement. These are the physical, technical, mathematical and statistical foundations necessary for a specific measurement. An equally important aspect is the preparation of the equipment itself needed for measurements. We are talking about the correct selection of measuring devices and measuring probes. Next comes the measurement, which is recorded and evaluated in measurement protocols.

The article presents an example of measuring the temperature of the working environment, in which the Technical Teaching department students measured the working environment's temperature with a classic thermometer and a globe thermometer. A globe thermometer is a device that can measure the temperature of the working environment when the worker's thermal well-being can be affected by, for example, airflow. Other factors, such as cold room walls, can also influence the ambient temperature. The reason may be the beginning of the heating season. The air temperature and the radiant temperature of the walls can therefore influence the final temperature in the room. Similarly, such temperature difference can be seen if a heat source in the room affects the ambient temperature. A globe thermometer is a thermometer that can record such an effect. A globe thermometer of the Vernon-Jockl type and a standardised thermometer according to the STN ISO 7726 standard is used. This thermometer consists of a copper ball with a diameter of 150 mm. The surface of the ball is covered with black paint. A thermocouple is placed inside the thermometer, usually connected to a device that records the temperature. This task was chosen so the students discover that two thermometers, designed to measure the temperature in the same environment, will ultimately record different values.

3 Measuring the Temperature of the Working Environment with a Globe and Classic Thermometer

During the practical lessons on Measurements and Measuring Instruments, the Teaching of Technology program students measured the working environment's temperature. The temperature of the working environment was affected by an electrical appliance, an electric stove with four plates. In the case of this measurement, the aim was to show the temperature change measured with a classic thermometer and a globe thermometer. The air temperature was measured using a device that recorded the temperature of the dry thermometer and air humidity. Anemometer/Psychrometer AN 340 (Figure 1) recorded these values. It is a device commonly used to measure microclimate values such as airflow velocity, air temperature, wet bulb temperature, relative humidity, and dew point temperature.

Fig. 1: Anemometer/Psychrometer AN 340

At the same time, the radiation temperature was also measured with a globe thermometer. This device recorded the temperature of the working environment affected by the radiant heat emitted by the electric stove. A Testo 435 measuring device with an attached globe thermometer probe was used (Figure 2). The location of the probe of the globe thermometer was at a distance of 50 cm from the edge of the stove. An Anemometer/Psychrometer probe AN 340 was also placed in this place.

Fig. 2: Location of the globe thermometer probe

The measurement was carried out on October 11, 2021, in a room with an electric stove with four plates switched on for 30 minutes. During this time, air temperatures, air relative humidity and the temperature of the globe thermometer were recorded at 5-minute intervals. After 30 minutes, the electric stove was turned off, and the temperature was recorded for another 30 minutes. The measured values are shown in Table 1. The values in the table marked in bold are the data measured when the stove was turned off.

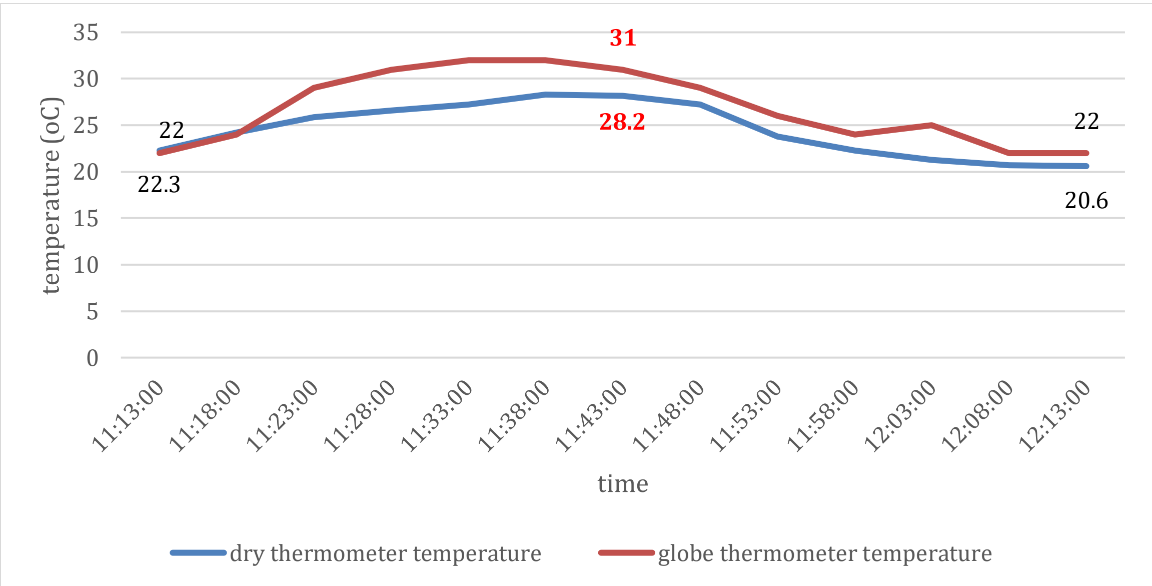
time	dry thermometer temperature (°C)	globe thermometer temperature (°C)	temperature differences (°C)	relative air humidity (%)
11:13:00	22.3	22	-0.3	48.5
11:18:00	24.2	24	-0.2	48.4
11:23:00	25.9	29	3.1	26.6
11:28:00	26.6	31	4.4	23.3
11:33:00	27.2	32	4.8	22.1
11:38:00	28.3	32	3.7	21.1
11:43:00	**28.2**	**31**	**2.8**	**21.1**
11:48:00	27.2	29	1.8	21.9
11:53:00	23.8	26	2.2	28.8
11:58:00	22.3	24	1.7	29.5

12:03:00	21.3	25	3.7	32.8
12:08:00	20.7	22	1.3	34
12:13:00	20.6	22	1.4	33.5

Table 1: Values of temperatures and relative air humidity

Figure 3 compares the measured values of the dry thermometer, the globe thermometer, and the relative humidity of the air. The graphs show the initial and final values from the measurement. The red colour showed the values when the electric stove was turned off. From the progress of the temperatures of the dry and globe thermometer, it is clear that the temperature of the working environment can be significantly influenced by the heat source, which in this case was an electric stove. The most significant difference between the dry and spherical thermometer temperature was recorded at 11:33 when this difference was up to 4.8ºC.

Comparing the progress of temperatures and relative air humidity, it was possible to observe a significant decrease in relative humidity only ten minutes after switching on the stove. In this case, the relative humidity in the room dropped from 48.5% to 26.6%. After this change, the humidity dropped even further to the lowest value of 21.1% at 11:43, when the stove was turned off. From this moment, the relative humidity of the air started to rise again. At the end of the measurement, it reached a value of 33.5%.



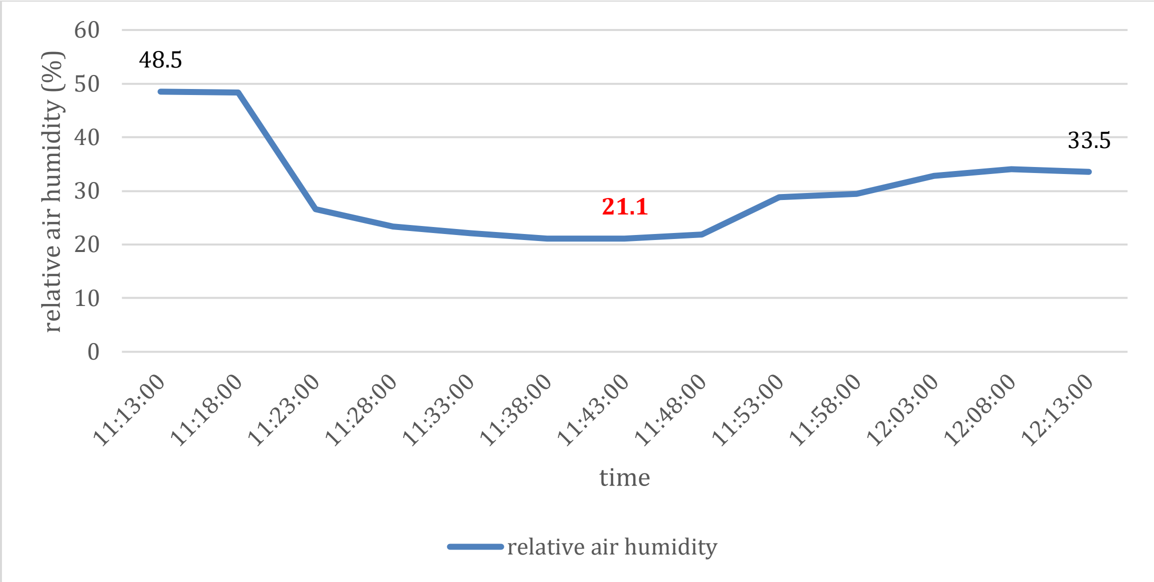


Fig. 3: Progress and comparison of measured values

4 Discussion

The measurement aimed to highlight the differences in the data obtained by measuring with a dry and globe thermometer. At the same time, students had the opportunity to acquire the necessary skills in processing measured data into protocols.

This measurement enabled the students to mainly perceive the differences between the temperature of a dry globe thermometer and the relative humidity of the air. This phenomenon is also often seen when the recorded temperature of the globe thermometer is lower than the temperature of the dry thermometer. For example, at the beginning of the heating season, when the heating element (radiator, fireplace, stove, etc.) warms the air in the room, the spherical thermometer shows lower temperature values because the surrounding walls need some time to accumulate the heat.

The students performed the measurements by working in two groups. The first group (7 students) focused on measuring the temperature with a dry thermometer, and the second group (7 students) recorded the temperature with a globe thermometer. Then, they shared the measured data. They wrote a protocol for the measurement, which had to be made in the following form:

Theoretical foundations of measurement: This part should describe temperature as a physical quantity and technical assurance of measurements, such as devices, legislative regulations, and technical standards.
Description of the measuring device (description and explanation of the construction): In this part, they described the environment where the measurement took place with the location of the measuring devices.

Method used: The accuracy of each measurement depends on the method used. The students had to determine and describe what measurement method it was.
Measurement procedure: Writing a brief but concise description of the measurement in the protocol was necessary.
Measured data: This part should contain all calculations, partial and central measured values, tabular expressions, units, and graphs.
Measurement evaluation and conclusion: In this part of the protocol, it was necessary to evaluate the measurement results themselves and to be able to interpret them about legislative regulations.

The qualitative analysis of the fourteen submitted protocols can conclude that the most frequent mistakes in the protocols were in the theoretical parts of the measurement. Formal errors like incorrectly defined units and their quantities often occurred in theory. The description of the instruments was often very brief. There was no indication of the accuracy of the instruments. Students do not always realise that such records of measurements need to be made so that anyone who repeats such measurements as described in the protocol should get the same results. It is the elementary basis of every scientific work.
A frequently repeated error was also the incorrectly selected graph type. Since the temperature was recorded over time, it was necessary to choose a line graph. In one protocol, the student chose a column type of graph to present the results.

The most significant lack of information occurred in the measurement evaluation section, where students often neglected to compare their measured data with the data established by legislation (decrees, standards). The students' conclusions based on the measurements were often just a dry statement of the measured data without a deeper analysis.

4.1 Conclusion

The article's results and evaluations of the student's activities show that simple measuring devices and methods can ensure a discovery approach to acquiring new knowledge and skills. In the current digital era, devices are used every day, which minimises the error of the observer and the experimenter but, at the same time, suppresses the creative approach to a certain extent. Digital devices reduce the demands on user knowledge and skills of experimenters. In our case, the difference in the measured values could have surprised the students. Two thermometers, placed in the same environment, at the same place at the same time, recorded different values. When analysing the measured values, students are forced to look for the causes of the difference. The experiment experience will help to remember better and understand the given issue. Our set concept of temperature measurement confirms the findings of Mack et al. l. that older measurement methods of technical quantities are more suitable for students not only for understanding the principle of measurement but also for understanding the structure of the measuring device and, thus also, the obtained results (2019).

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