A Case Study of Pre-service Teachers' Physics Laboratory Skill in Measurement and Uncertainty

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Abstract
In a physics laboratory, an experimental result and its uncertainty are significant because they permit others to evaluate the quality of the experiment. This is the most essential competency for high school science teachers. The purpose of this study was to explore laboratory skills in physics, particularly measurement and uncertainty. Data were collected from pre-service science teachers and pre-service physics teachers during the academic year 2022. The participants were given a measurement and uncertainty exam during class. Their responses were analyzed using the following procedures: reading an estimated value and uncertainty from a measurement, giving the uncertainty from the repeated measurement, propagating uncertainty, and writing the final results. The test revealed that the majority of responses lacked knowledge of uncertainty and the propagation of uncertainty. They provided incorrect answers and were unable to provide reasonable responses. In this work, the results will be discussed, along with the future direction of the research.

Keywords: Physics Laboratory Skill, Measurement, Uncertainty, Pre-service Teacher

Introduction

An accuracy of an experimental result is essential for the scientific process. Each measurement has an associated uncertainty; therefore, for the accuracy of the interpretation, the measured data need to be accurate and precise. Normally, high school physics courses connect physics theory with practicing in order to help students improve experimental skills (Parappilly et al., 2018; Ruhaisa & Jiradawan, 2018). This is an important skill for physics teachers to help engage the students learning correctly. For our investigation, we found that the students who completed the fundamental physics laboratory courses often neglect the measurement uncertainty. In addition, this can lead to the problem that students consider a data record as a number without interpreting its significant figure (Jirungnimitsakul & Wattanakasiwich, 2017; Ruhaisa & Jiradawan, 2018).

This study investigates the high school physics laboratory skill, in particular, measurement and uncertainty from pre-service science teachers, pre-service physics teachers, and in-service teachers. This practical skill is important for the pre-service teachers to understand how to teach physics laboratory.

Methodology

Participants

Data were obtained in the academic year 2022 from undergraduate students including, 23 pre-service science teachers and 21 pre-service physics teachers. The researches were extended to 11 in-service physics teachers who have an experience to teach high school physics laboratory.

Measurement and data collection

In this study, the Thai version of the measurement and uncertainty test was constructed based on physics textbooks (Taylor, 1997). The test was distributed to the participants during the laboratory class. There were five open-ended questions designed to evaluate students' understanding and skills of measurement and uncertainty. The students were asked to solve and find the final answer to each question. The students were required to complete the test in 30 minutes. The data from the in-service teachers were collected at the same condition. All of their responses were analyzed based on reading an estimated value and uncertainty from a measurement, giving the uncertainty from the repeated measurement, making propagation of uncertainty, and writing the final answers.

The questions

Question 1: The result of measuring the diameter of a five-baht coin by using a ruler is shown in figure 1.

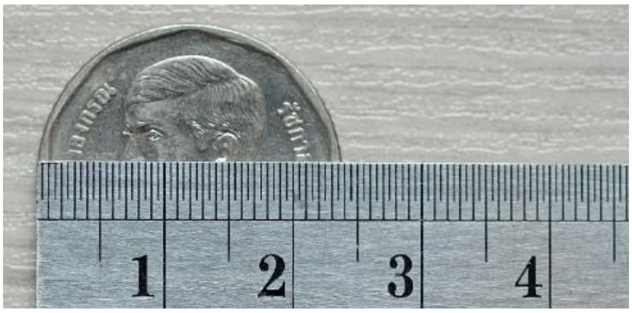

Figure 1: Measurement with a ruler

What is the diameter of the coin including its uncertainty from a single measurement that should be reported in the result?

Question 2: The result from measuring the diameter of a five-baht coin by using a vernier caliper is shown in figure 2.

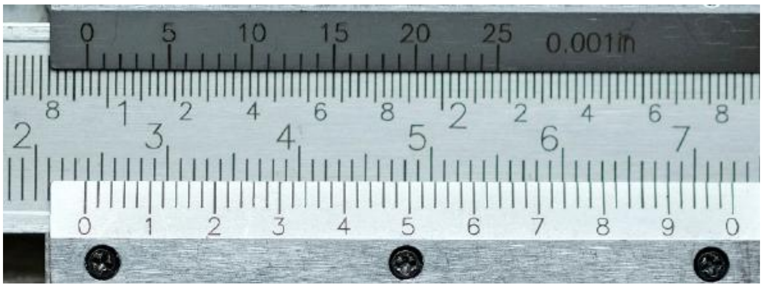

Figure 2: Measurement with a vernier caliper

What is the diameter of the coin including its uncertainty from a single measurement that should be reported in the result?

Question 3: Select the appropriate diameter of a coin, between the answer in Questions 1 and 2, to calculate the area of a coin including its uncertainty.

Question 4: Measure the length of an object. The length of this object should be reported 6 times (in millimeters) with an instrument with an uncertainty of 0.1 mm. The length is measured to be 23.1, 22.8, 22.7, 33.2, 23.0 and 22.6 respectively. How the object length should be reported?

Question 5: The length of the spring hanging in a vertical line with a stand is 56.1 ± 0.2 cm. After that, hang the lower end of the spring with clips, the length of the spring then becomes 59.56 ± 0.06 cm. What is the change in the length of this spring including its uncertainty?

Scoring and analysis

After the process of data collection, the answers of this work were analyzed by giving five marks for a full score. Each question was given one mark for the correct an estimated value and uncertainty. If they provided only the estimated value without the uncertainty, we gave them 0.5 mark. Another incorrect answer was zero. The answers of all participants were marked by the same researcher.

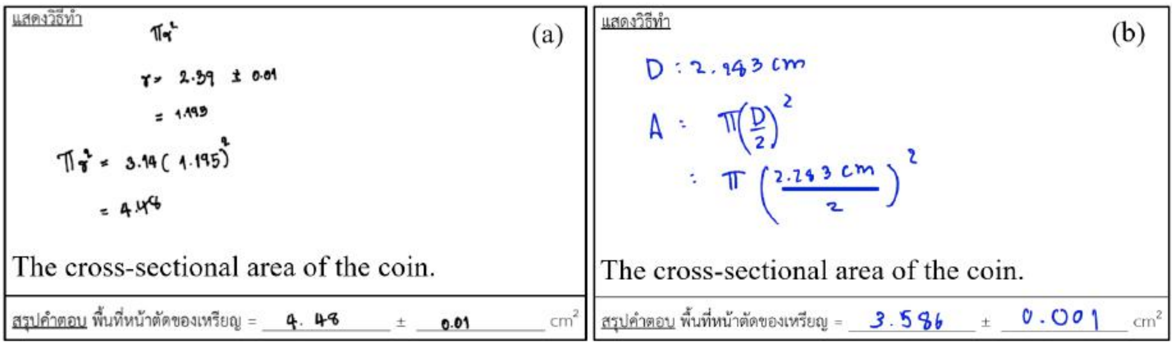

Figure 3: The incorrect answers were from question 3: (a) the answer from pre-service science teachers and (b) the answer from pre-service physics teachers

Results and discussion

Overall, all three groups average scored higher than 50%. In-service physics teachers had the highest average score. The average scores and standard deviation are presented in Table 1. All groups performed the lowest scores on question 3, propagation of uncertainty. Examples of incorrect answer in the question 3 is shown in figure 3. The students handed on the answer without the calculation part of an error and gave the error from the radius *r*. Actually, the possible answer could be 4.471 ± 0.007 cm^2. In this case, they might just understand error of propagation from the theory, but they did have difficulties in applying it to the real context.

Table 1: The mean score and standard deviation for each question in each group

	pre-service science teachers (N=23)	pre-service physics teachers (N=21)	in-service physics teachers (N=11)
Question 1 (a single measurement)	0.74 ± 0.44	0.90 ± 0.29	0.77 ± 0.39
Question 2 (a single measurement)	0.59 ± 0.48	0.86 ± 0.35	0.68 ± 0.44
Question 3 (propagation of uncertainty)	0.35 ± 0.48	0.10 ± 0.20	0.68 ± 0.32
Question 4 (repeated measurement)	0.64 ± 0.22	0.69 ± 0.13	0.75 ± 0.24
Question 5 (propagation of uncertainty)	0.54 ± 0.41	0.62 ± 0.26	0.82 ± 0.39
Overall test (full = 5.00)	**2.86 ± 0.42**	**3.17 ± 0.30**	**4.08 ± 0.37**

From the results shown in Table 1, it can be seen that there is a difference between each group. The in-service physics teacher will have the highest score at 4.08 ± 0.37. The lower scores were the pre-service physics teachers and the pre-service science teachers at 3.17 ± 0.30 and 2.86 ± 0.42, respectively. Comparing the scores in questions 3 and 5 of pre-service science and physics teachers to the in-service physics teachers, we found that the lower scores were from misunderstandings for finding the propagation of uncertainty. These are similar to other studies and important data for using for improving their laboratory skill (Jirungnimitsakul & Wattanakasiwich, 2017; van Kampen & Gkioka, 2021).

Conclusions

The results from the test revealed that the pre-service science and physics teachers had lower skill than the experienced teacher especially the propagation of uncertainty. Measurements and uncertainty are the core of physics, and it is important that the student teachers develop an understanding of this topic for transferring in future teaching. The possible reason is that students lacked studying and practicing the prior knowledge of measurement for high school physics. This may cause their weakness to apply the concept to real situations (José Luis, 1999). The results would be benefit to this research and the other researchers to use as a guideline to improve the quality of teaching and learning physics laboratory for pre-service teachers.

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