Sense of scale for prospective teacher students in solving physics problems

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Abstract. Thinking about the boundary conditions for the formulation of abstract physical principles is needed in solving physical problems. A physics equation cannot simply be applied without regard to the context and requirements that the equation must fulfill. This study has explored the sense of scale in the context of solving physical problems in prospective teacher students, using qualitative descriptive analysis. Respondents consisted of 37 1st semester students, 35 5th semester students and 20 Physics teacher professional education (PPG) students at UNNES. The results of the study showed that sense of scale in solving physical problems in first and fifth semester students was low, while in professional education students were classified as moderate. There was no difference in the understanding of the scale between male and female students. Sense of scale about the measurement limit of a measurement instrument was better. Sense of scale in understanding the boundary conditions for the application of a physical formalism, identifying variables and constants according to context, and predicting a phenomenon based on the finding data was still relatively low.

1. Introduction

Sense of scale is one of the generic thinking skills in science / physics [1], namely an awareness of the scale of a quantity or event or phenomenon in solving physics problems. Generic science skills have a very important role in increasing students’ understanding of existing physics theories and concepts and in supporting learning by emphasizing science processes and products [2]. Generic skills enable us to generate new skills that help us succeed in new situations, manage and adapt to changes and to flourish by creating what matters even in the face of diversity [3]. The process skills in learning will be more meaningful when student's thinking skills and metacognitive skills that are optimally developed [4]. In the process of identifying problems, one uses thinking skills and metacognition skills simultaneously, resulting in problem solving steps. The planning process requires metacognitive knowledge [5]. Thus, the sense of scale is part of a combination of metacognitive strategies and critical thinking in the process of identifying problems.

In solving physics problems, students first need to have the skills to identify problems well, then plan the steps to solve. In the early stages of solving this problem, students need critical thinking and metacognition strategies [4] especially the planning strategy. There are two basic components in metacognition in solving problems that are metacognition knowledge and awareness of self regulation [5,6]. Sense of scale is very necessary in determining the direction of solving physics problems. In this study the sense of scale that is to be studied includes: (1) understanding the boundary conditions in the application of the principles of physics, (2) predicting phenomena based on data, (3) estimating the
limits of measuring instruments used in measuring quantities, and (4) identifying quantities variables and constants according to the context.

2. Methods
Respondents in this study consisted of students at prospective physics teachers’ learning programs, namely: 37 1st semester students, 35 5th semester students, and 20 Physics Teacher Professional Education (TPE/ PPG) students at UNNES.

Data collected through written tests, including sense of scale related to: understanding boundary condition for the application of a physical formalism, predicting a phenomenon based on the finding data, finding measurement limit in measure quantity using instrument, identifying variables and constants according to context. Constraints in working on tests were identified through questionnaires and interviews. Data were analyzed using qualitative descriptive. In this study also investigated the sense of scale of respondents based on gender differences and semester level of students.

3. Results and Discussion
Data collecting method in this research consists of sense of scale for prospective teacher students based on gender differences, semester levels and descriptions of students' sense of scale in solving physics problems. Interviews were conducted with the aim of confirming students' work.

3.1. Description of student sense of scale based on gender differences and semester level
The study conducted shows that there are differences between male and female in previous physics and math knowledge [7]. Differences based on gender are also found in social problem-solving abilities [8]. According to Melzer, although in many cases male-female differences are relatively small, it was found that women had a higher level of error in the problem of circuit diagrams compared to men, although men and women had received the same instructions [9]. Efforts to reduce gender gap have been made through teaching with certain interactive strategies [10]. In this study also examined the sense of scale based on gender as presented in Figure 1. The results showed that there was no difference in sense of scale between male and female in first semester students, fifth semester and TPE/ PPG students.

![Figure 1. Student's sense of scale based on gender differences](image)

Based on Figure 1 it is known that the sense of scale is not influenced by gender differences. Academic interactions between male and female are likely to be able to reduce gender disparities in student thinking. The sense of scale according to the semester level shows that the score is classified as low to moderate, as shown in Figure 2.
Figure 2. Sense of scale based on student semester level

Student's sense of scale scores as in Figure 2 show that students in solving problems are not used to carefully considering the physics problems given. They generally examine the problem superficially, then apply the formula according to the problems commonly encountered. PPG students have a better concept and have more experience in solving Physics problems, so they have a better sense of scale.

One of the crucial problems commonly faced by students in solving physics problems is the mistake in interpreting questions [11]. Various investigations show that "Novice" categorizes physics problems based on surface content encountered only, while "Experts" not only consider surface content but also the underlying principles and concepts [12]. Thus, it can be said that the ability of students to interpret the physical problems presented is still low, while also indicating mastery of the Physics concept is not good.

3.2. Analysis of sense of scale in prospective teacher in solving physics problems

Sense of scale studies in solving physics problems include how to understand the boundary conditions of a physical formulation, predict based on data, determine the limits of measuring tools, and identify variables and constants. Studies on prospective Physics teachers are categorized into three levels of students, namely 1st semester, 5th semester and TPE/PPG, presented in Figure 3.

Figure 3. Description of sense of scale prospective teacher in solving physics problems

The results show that determining the limit for measuring an instrument has a better sense of scale. Students can choose the limit for measuring an ammeters or voltmeter that is appropriate for a
measurement. However, students generally do not understand well about the boundary conditions of a Physics formulation. They generally only understand the application of an equation without understanding the related boundary conditions. For example, in examining the Sound Doppler effect, they did not realize that the equation was no longer valid when the sound source speed had exceeded the sound velocity. Similarly, in estimating the temperature of a mixture or other physical phenomenon, experts apply the principle of problem solving in an organized manner, using self-monitoring strategies because they are guided by metacognition, while novices usually focus on trying to match problems with mathematical procedures [13].

In general students do not realize that a physics equation will have special properties when applied to a particular context. They are not careful in identifying which variables and constants in a particular context. For example, when a wave propagates through a medium, its velocity and wavelength will change according to the characteristics of the medium, while the frequency is fixed. Of course, this will be different when the polychromatic light undergoes disperse through a prism. It has a constant speed, while the wavelength and frequency change. Sense of scale related to identifying a quantity is very important in planning problem solving. Research shows that students often focus on identifying the principles used in problem solving but cannot identify appropriate principles [12]. Experts use the fundamental concepts of physics in solving problems, while students recognize problems based on surface features [14].

Thinking skills that are very important to be developed in physics problem solving are making predictions based on data. For example, students have difficulties in predicting collisions that will occur, estimating the state of the object based on the data presented. Studies show that students often predict and infer not based on observation and experimentation but according to their initial knowledge [15].

4. Conclusion

Based on the results of this study, it can be concluded that the sense of scale of prospective teacher students is low. The ability to estimate the limits of measuring an instrument is better, while in understanding the boundary conditions of a physics formulation, identifying variables and constants, and predicting phenomena based on data is relatively low. There is no difference in sense of scale based on gender.

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