Critical thinking skills and science process skills in physics practicum

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Abstract. The purpose of this article is to analyze the differences between indicators of science process skills and critical thinking skills in physics practicum. Both of these skills have the same indicators but certainly have differences. How to distinguish definitions and measurements of science process skills and critical thinking skills that are interrelated such as interpretation, inferring and predicting. These three indicators have different meanings in aspects of science process skills and critical thinking skills. The research method used is a literature review with descriptive analysis. The data used in this study are secondary in the form of articles, reports and books relating to science process skills and critical thinking skills in physics practicum. The data collection method used in this study is the documentation method. The analysis shows that the three intersecting indicators have different definitions and measurements. Therefore, in physics practicum, science process skills and critical thinking skills must be measured with different instruments and with different treatments. Critical thinking skills emerge after mastering content and concepts well and comprehensively, while science process skills are trained through the process to obtain physical concepts and content.

1. Introduction

Physics Practicum is one of the courses programmed in a physics education study program in one of the LPTK in Aceh Province as a subject of study program expertise. In physics practicum, the expected competency is for students to understand physics as products, processes and attitudes \cite{1}. Science products can be found in facts, principles, laws, theories as conclusions from a series of scientific processes. The process or method can see from the ability to solve problems, design and conduct experiments, evaluate data, measure, make reports and provide information. At the same time, attitudes arise in individuals who carry out this scientific process, clearly visible beliefs, values, opinions, thinking, behaving and acting \cite{2}.

Physics as a process is the steps or methods in obtaining the knowledge of physics. In physics practicum, these steps as a process are called science process skills. Science process skills consist of two categories, primary and integrated skills. Primary process skills include observing, deducing, measuring, communicating, classifying, predicting. Integrated process skills include controlling variables, defining operations, formulating hypotheses, formulating models, data and interpreting experiments \cite{3}.

During the physics practicum course, students will be trained with practical performance skills using the science process skills approach, and then students will have critical thinking skills. As a prospective
physics teacher, students of physics education study programs must have graduate competencies who have broad insight and are ready to face the real world in the 21st century with the need for 4C skills [4]. Therefore, physics practicum that as one of the subjects of the study program expertise must be able to support the performance of prospective teachers and equip students in developing skills in designing, implementing and managing learning activities [5].

Critical thinking skills (CTS) are self-regulation in deciding (judging) something that results in interpretation, analysis, evaluation, and inference, as well as exposure using evidence, concept, methodology, criteria, or contextual consideration that forms the basis of decision making [6]. Critical thinking skills have two fundamental roles in learning and practicum in physics, in the part of learning to build ideas and responsibilities in applying concepts and understanding. At the same time, CTS in practice often arises through activities of arguing, discussing and defending ideas [7]. CTS and Physics practicum activities are interrelated, namely, in solving problems through evaluation, careful and thorough testing, rejecting and accepting arguments [8] and or evaluating arguments [9].

Science Process Skills (SPS) as called a process of understanding scientific investigation methods and procedures [10] to discover a science/physics concept. Two other essential dimensions of science besides science products are the scientific process and scientific attitude. The method of doing science is a science process skill that is used by scientists in the process of discovering science concepts [11]. Science consists of three essential dimensions, namely scientific products, scientific methods, and scientific attitudes. Therefore SPS is a skill in the process of discovering scientific concepts [12],[13].

2. Methods
This type of research is library research, which is a series of studies relating to library data collection methods, or the analysis of which research through various library information (books, scientific journals, newspapers, magazines, and documents) [14]. Literature research or literature review is research that critically studies or reviews knowledge, ideas, or findings contained in an academic-oriented literature body and formulates theoretical and methodological contributions for a particular topic. The focus of library research is to find various theories, laws, propositions, principles, or ideas to analyze and solve research questions formulated. The nature of this research is descriptive analysis, namely the regular breakdown of data that has been obtained, then given an understanding and explanation so that the reader can understand it well [15].

The data used in this research is secondary data. Secondary data is data obtained not from direct observation [16], but data collected from the results of research conducted by previous researchers. The secondary data sources referred to are primary and original books and scientific reports contained in articles or journals regarding science process skills and critical thinking skills in physics practicum. The data collection method used in this study is the documentation method. The documentation method is a method of collecting data by finding or extract data from the literature in accordance with the problem formulation [17].

The primary source of this research is an article written by Tiruneh in 2018 with the title Designing Learning Environments for Critical Thinking: Examining Effective Instructional Approaches. Springer published this article in 2018. The report was used as the primary source of research with several considerations, the first because the material is following the formulation of the research problem. Secondly, this article presents a detailed analysis and research data, including displaying examples of measurement instruments in physics practicum. Lastly, the reputable international journal, Springer, was published in this article, so it is very worthy of being used as a reference.

In this article, Tiruneh presents data-domain-specific to critical thinking skills after learning with three conditions of teaching, namely immersion, infusion and control. Tiruneh tests the teaching that implements immerse and systemic infusion and the teaching of control systems. Tiruneh found that students who followed immerse and infusion learning had a significant advantage compared to students who took control of learning. Tiruneh then recommends a specific domain of critical thinking skills that can be used in the measurement of critical thinking skills in physics practicum and physics learning.
Another primary source in this research is an article written by Ozgelen in 2012 under the title "Students' Science Process Skills within a Cognitive Domain Framework" published in Eurasian Journal of Mathematics, Science & Technology Education. Aside from being following the formulation of the research problem, this article it presents specific data related to science process skills and their relation to the cognitive domain so that it is more detailed in conducting analysis for this research.

3. Result and Discussion

3.1 critical thinking skills

CTS is a mental process, strategy, and representation that people use to solve problems, make decisions, and learn new concepts [18][19]. Critical thinking can be defined as the use of cognitive skills or strategies to describe the thoughts involved in solving problems, formulating conclusions, determining possibilities, making decisions, reasoning and arguing. CTS is closely related to a strong understanding of specific material content [20], increased decision making related to complex real-life problems [21][22], so, CTS is highly dependent on content knowledge with certain specific domains, and thus, knowledge of content that is depth of a particular domain is required for CT competence. Figure 1 shows the process of achieving and producing critical thinking skills in a physics practicum activity.

![Figure 1. Critical thinking skills process in physics practicum](image)

Figure 1 shows the process of achieving critical thinking conditions in a physical practicum activity through general, infusion, immerse and mixed approaches. In the general plan, CTS is taught separately from the presentation of the existing subject matter content. The infusion approach integrates CT instruction in standard subject matter and makes CT general principles explicit to students. In this approach, students are encouraged to acquire and explicitly practice CT skills through the structured subject matter. The immersion approach also tries to incorporate CT into instructional material. However, general CT principles and procedures are not made explicit for students assuming that they will acquire thinking skills as a consequence of involvement in subject matter instruction. The mixed approach consists of a combination of general methods with a joint infusion or immerses approaches. In a mixed approach, there is a unique session course aimed at teaching general principles of CT. Still, students are also involved in CT instruction as a particular subject where the purpose of CT is explicitly or implicitly [23]. I CTS aspects and specific domains that have been formulated in several studies related to CTS with electromagnetic content [24]. Table 1 shows aspects of critical thinking skills and specific areas.
| The CTS aspect         | Specific Domain                                                                 |
|-----------------------|----------------------------------------------------------------------------------|
| Reasoning             | Recognize statement errors                                                       |
|                       | Recognize Measurement errors                                                     |
|                       | Interpretation of experimental results                                            |
| Hypothesis            | Identification of the causal relationship of a symptom/event                     |
|                       | Check the adequacy of observations/samples/repetition of experiments to draw conclusions |
|                       | Check for adequate sample sizes and possible biases when generalizing            |
| Argument Analysis     | Identify important parts of the argument                                          |
|                       | Summing Up the Right Statement Based on a Data Set                                |
|                       | Criticize the validity of generalization from the results of the experiment       |
| Analysis of Possibilities and Uncertainty | Predicting the Possibility of an Event (by understanding the limits of extrapolation) |
|                       | Identifying Assumptions (e.g. Recognizing Assumptions What Must Be Defended In Generalization Of Experiment Results) |
|                       | Understand the Need for Additional Information in Making Decisions                |
|                       | Make valid predictions                                                            |
| Problem-solving and decision making | Identify the best alternative in solving problems                                |
|                       | Check Procedures That Are Appropriate In Solving Problems                         |
|                       | Evaluating Solutions for a Problem                                                |
|                       | Make strong decisions based on available evidence                                 |
|                       | Use analogies to solve problems                                                   |

### 3.2 science process skills

SPS is a process of understanding scientific investigation methods and procedures [25] to discover a science/physics concept. Two other vital dimensions of science besides science knowledge are the scientific process and scientific attitude. The method of doing science is a science process skill that is used by scientists in the process of discovering scientific concepts. Science is from three essential dimensions, namely scientific products, scientific methods, and scientific attitudes. Therefore, SPS is a skill in the process of discovering scientific concepts. Figure 2 shows how science was formed and the position of SPS in it.

![Figure 2. Process skills in physics practicum](image)

Figure 2 above shows that SPS is one of the processes that must be taken by students to understand science as a whole as a comprehensive concept. Students can learn about how to use some scientific equipment and/or follow some standard scientific procedures. There are six basic science process skills, namely Observation, Communication, Classification, Measurement, Inference, Prediction [26].

Observing is a fundamental science process skill. Observe the objects and events using all the senses that are owned. The ability to make useful observations is also crucial for the development of other science process skills: communicating, classifying, measuring, inferring, and predicting. SPS can be integrated with several indicators, such as interpreting data (graphs, tables and ability to build arguments), making appropriate graphs from, asking questions, ability to make hypotheses that can be tested and the ability to design experiments. Some indicators of process skill skills are also contained in
the specific domains of, namely Interpretation, Concluding and Predicting. There can develop students' understanding of the scientific approach of inquiry.

3.3 analysis of the relationship of CTS indicators with SPS

Table 2 below presents data on the Analysis of indicators or domain-specific CTS that are interrelated with SPS, with aspects of analysis on how to develop both skills, work domains and operations.

Table 2. analysis of specific domains contained in CTS with SPS

| Aspect of Analysis | CTS                                                                 | SPS                                                                 |
|--------------------|----------------------------------------------------------------------|----------------------------------------------------------------------|
| How to Develop     | Trained with four approaches to learning:                           | Be trained in the process of finding a concept. Usually in an experiment or practicum. |
|                    | 4. General, CT is taught separately from the presentation of subject matter content |
|                    | 5. Inversion, integrating CTS instructions in instructional material and making general CTS principles explicit to students |
|                    | 6. Immersion, try to include CTS in the subject matter instruction. However, general CT principles and procedures are not made explicit for students assuming that they will acquire thinking skills as a consequence of engaging in the instructional subject matter. |
|                    | 7. Mixed, a mixture of the three previous approaches. CTS is integrated into learning, but also provides a special time to explain the CTS to students |
| Working Domain     | Mental activity (judging, evaluating, Analyzing, Gives an argument, Accept or reject arguments) | Motoric/physical activity, Based on observation/observation |
| Specific domains that are interrelated |                                                                      |                                                                      |
| Interpretation     | ➢ Ability to understand, explain the meaning of a situation, experience, explain problems, describe information, event data and decisions. | ➢ Present the results of an experiment in the form of a picture, graph, or table, |
|                    | ➢ Understanding to express the meaning or significance of various experiences, situations, data, events, judgments, habits, beliefs, rules, procedures, or criteria | ➢ Determine the correlation between variables, |
|                    | ➢ The process of finding, determining, or establishing meaning. Interpretation skills can be applied to anything, e.g. written messages, charts, diagrams, maps, graphs, memes, and verbal and non-verbal exchanges. People use their interpretive skills to behaviours, events, and social interactions when deciding what they think means in a particular context. | ➢ Comparing experimental data with hypotheses, and |
|                    | ➢ The activities of the human mind are based on the understanding/knowledge they have to reach new understandings | ➢ Summing up the results of an experiment |
| Make conclusions   | ➢ Ability to identify and choose the elements needed; to draw conclusions that have reasons, to suspect and set up a diagnosis, to consider what information is required, and to decide the consequences that must be drawn from data, information, statements, events, principles, opinions, concepts and so forth. | ➢ Discuss what was found in connection with the original question |
|                    | ➢ The activities of the human mind are based on the understanding/knowledge they have to reach new understandings | ➢ Compare their findings with their previous predictions |
|                    | ➢ Identify patterns or trends in their results? | ➢ Pay attention to the relationship between changes in one variable and another? |
|                    | ➢ Examine all patterns or trends against all evidence? | ➢ Identify patterns or trends in their results? |
|                    | ➢ Draw conclusions that are summarizing and consistent with the evidence? | ➢ Examine all patterns or trends against all evidence? |
|                    | ➢ Use logic to make conclusions from what was observed | ➢ Draw conclusions that are summarizing and consistent with the evidence? |
| Predict            | ➢ Understand the probability and likelihood of an event | ➢ Predictions (scientific guesses) are based on useful observations and conclusions made about observed events. |
|                    | ➢ Estimating the plan and its consequences | ➢ Predictions; based on what we observe and also our past experiences with the mental models we have built from that experience. |
|                    | ➢ The skills needed to understand the probability of success and failure in academic and everyday decision making | ➢ Estimates specifically what will happen in future observations. Scientists often make predictions or predictions based on observations, measurements, or studies that show trends in certain symptoms. |
|                    | ➢ What will happen? If I do this, this will happen. How do we know what will happen? What will we do to find out what happened? | ➢ What will happen? If I do this, this will happen. How do we know what will happen? What will we do to find out what happened? |
Abdul and Doni got the assignment to make paper airplanes as a project after carrying out practicum on Bernoulli's law. Abdul and Doni had planned to make paper airplanes by varying their wingspan with three types of aircraft wings. Abdul did the test after adding a paper clip in the middle of the plane by giving the same speed using his hands so that the paper airplane could fly. The following is Abdul's experiment data.

| Airplane Type | Experiment Average | CTS | SPS |
|---------------|-------------------|-----|-----|
|               | s(m) | t(s) | v(m/s) | s(m) | t(s) | v(m/s) |
| Type 1        | 10.25 | 3.56 | 2.88   | 10.25 | 3.56 | 2.88   |
| Type 2        | 8.00  | 2.92 | 2.74   | 8.00  | 2.92 | 2.74   |
| Type 3        | 7.75  | 3.33 | 2.33   | 7.75  | 3.33 | 2.33   |

Based on the experimental data, Abdul and Doni made a statement as follows:

- **Abdul:** If the wingspan is increased, the flight distance will be shorter.
- **Doni:** The shape of the wing plane curved downward will fall further than curving upward or straight.

In your opinion, whose statement is most consistent in applying the Bernoulli principle? Give your reasons.

### 4. Conclusion

After analyzing various kinds of literature, it was concluded that in the practicum of physics, CTS could be trained with general approaches, immersion and infusion. In addition to CTS, physics practices can also be developed through science process skills to find and gain an understanding of physics concepts. Both of these skills have the same measurement indicators, including interpretation, drawing conclusions and predicting. The measurement of the three interrelated indicators on each of these skills must be measured using different instruments and with different treatments.

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