Cognitive Process of Pre-service Science Teachers Using Problem-based Learning on Nervous System Concepts

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Abstract

Cognitive Process (CP) is a mental process that occurs when a person forms new knowledge with fully conscious or unconscious actions. This study aimed to obtain an overview of the CP of students who are pre-service science teachers in learning the nervous system using a problem-based learning model. The sample of the research was 37 student pre-service science teachers, who were taking the 4th semester. Students' CP is measured using a CP instrument that refers to Marzano's taxonomy. Data is analyzed by looking at the average value and frequently occurring answers, then interpreting the findings with the underlying theory. The description of 4th semester pre-service students in science education on nervous system concepts shows that the ability to think in the cognitive system has not been well formed compared to the ability to believe in the metacognitive system and self-system. Based on these conditions, developing more appropriate learning strategies to develop the CP of science teacher candidates is still necessary.

Keywords: Cognitive Process, Pre-service Science Teachers, Nervous System Concepts, Problem-based Learning

INTRODUCTION

The main aim of education is to develop students' thinking processes so that they are ready to face the challenges they face. The Cognitive Process (CP) is a mental experience for every student. The mental experience that occurs in students is influenced by the knowledge they have. Knowledge developed in learning is tiered with different levels of difficulty and complexity. This is done according to students' growth and development stages, especially their thinking abilities. The development of thinking in students does not just happen but has stages of the thinking process. Information, mental processes, and physical processes experienced by students will build knowledge domains and different knowledge used in thought processes correlated with cognitive systems, metacognitive systems, and self-systems (Marzano & Kendall, 2007).

The cognitive system has four levels, namely 1. knowledge retrieval, 2. comprehension, 3. analysis, and 4. knowledge utilization. Knowledge retrieval is the lowest cognitive system or level 1 with the ability to recall and execute categories. Comprehension, or level 2, has categories of synthesis and representation abilities. Analysis of level 3 has categories of matching, classifying, error analysis, generalizing, and specifying abilities. Knowledge utilization, or level 4, has decision-making, problem-solving, experimental inquiry, and investigation categories. The four levels are tiered and continuous, where every cognitive process of each learner will not be the same. This happens because the cognitive of students is a dynamic structure that will find different structures and mechanisms (Lira & Gardner, 2020).

The development of the cognitive system is continued at the metacognitive system, which is level 5. This stage includes specifying learning goals, monitoring the execution of knowledge, monitoring clarity, and monitoring accuracy. The metacognitive system is the ability to set goals and track how well they are being achieved. In other words, the metacognitive system controls the level of achievement of learning that has been done. Metacognitive abilities contribute highly to the level of cognitive abilities (Bahri & Corebima, 2015).

The self-system is the final stage of the thinking process, or level 6. This last level is the ability to control in deciding whether to continue a new activity or not. This level includes beliefs about the importance of knowledge, beliefs about efficacy, and emotions associated with knowledge.

Every learner must be able to make the right decisions on their problems. This is in line with research (Omarchecska, 2021), which states that students who argue highly also have high decision-making abilities. Learning that encourages independent learning can improve decision-making as part of self-system abilities (Muthukrishnan, et al., 2019).

Various factors can affect the development of students' CP. Internal and external factors have the same influence. Basic abilities, learning styles, and learning motivation are internal factors of students that influence their learning processes and outcomes. External factors, including learning strategies, learning media, teaching materials, student worksheets, and evaluation tools used by teachers during learning, will have a big influence on CP.

Appropriate learning strategies are needed to provide learning spaces that are in accordance with the characteristics of students. The diversity of students' characters requires teachers to create a learning process that bridges students to develop their thinking processes. Learning strategies that pay attention to the characteristics of concept/material representation and involve students actively can improve learning outcomes (Erlin, et al, 2021; Grau et al, 2021; Adams & Dewsbury, 2020; Zangerolamo, et al., 2020; Cardozo, et al., 2020; Gonzales, et.al., 2020; Khursid, et al., 2020; Kadarusman, et al., 2020; Quiroga & Choate, 2019; and McQueen & McMillan, 2018). Learning strategies must also construct mental models in order to achieve higher mental models (Yuanphan & Nuangchalerm, 2023), and provide opportunities for students to explore resources in solving problems (Daines, et.al., 2019). The use of the Problem-based Learning (PBL) model in learning is an effort to select learning strategies that can provide opportunities for students to process information appropriately in solving given problems and can improve problem-solving skills and student learning achievements (Sakir & Kim, 2020; and Tanti et.al., 2021). PBL was effective in increasing the level of metacognitive awareness of students (Tosun & Senocak, 2013).

Selection and use of appropriate learning media must also be done. The use of visual external representation media in relevant learning can improve conceptual understanding (Lira & Gardner, 2020; Hansen & Richland, 2020; Reineke, Kynn, & Parkinson, 2020; Judge, Carazes, Thomson, & Skidmore, 2020, McQueen & McMillan, 2018; Guy, Byrne, & Dobos, 2017; and Nichols, 2017). Using images as

learning media and evaluation tools can also improve students' conceptions (Reinoso & Iglesias, 2020). Media use also impacts pleasure and motivation (Bork et al., 2020). Learning media must also be a new learning resource for students (Ainscough, Leung, & Colhorpe, 2019).

Teaching materials, student worksheets, and evaluation instruments also influence learning success. The assessment instrument developed must measure students' abilities appropriately (Villafañe et al., 2021). Using appropriate instruments in learning will improve cognitive abilities (Rickey, et al, 2023; Halpin, et al, 2020, Prevost & Lemons, 2016).

This research uses nervous system material because, based on the results of interviews with science teachers at the MGMP Serang District, the nervous system is a difficult material to understand, even though this material is very important and must be taught back to students. The combination of morphology and function of organs with different characteristics makes nervous system material difficult to study (Cardozo et al., 2020; Martini & Nath, 2028; and Kurnadi, 2009). So, it requires a separate strategy to convey it.

Knowing students' CP is an important basis for developing the lecture process. The purpose of this research is to obtain an overview of the CP profile of pre-service science teacher students in learning the nervous system using a problem-based learning model. Research question: What is the profile of the thinking process of pre-service science teacher students in learning the nervous system using a problem-based learning model?

METHOD

Data were obtained by using qualitative research methods by looking at the phenomena that occur. The general phenomenon method is used to investigate cases that have meaning but cannot be understood in detail (Yıldırım & Şimşek, 2006). In this research, how participants understand, describe, and experience a phenomenon such as notions, ideas, or emotions is examined exclusively (Creswell, 2020). The data obtained was analyzed by looking at trends in students' answers and then interpreted based on the underlying theory. The thinking process of pre-service science teacher students in learning the nervous system using a problem-based learning model is studied with essay questions developed by Marzano & Kendall (2007).

Participants

This research was conducted in the even semester of the 2021/2022 school year. The research subjects were 4th-semester science education teacher

candidates or pre-service science teachers who contracted the Animal and Plant Physiology course for the 2021/2022 academic year at a university in Banten province.

Pre-service science teachers. have carried out lectures on the concept of the nervous system in the Animal and Plant Physiology course using the Problem-Based Learning learning model with lecture steps 1. Students are given an orientation to problems related to the nervous system, 2. Students work in predetermined groups, 3. Conduct investigations to solve problems related to concepts that must be resolved, 4. Make reports and present the results of investigations, and 5. Conduct reflection on the learning process that has been done.

Cognitive process test

The data was collected using the question instrument in the form of a description of 10 questions based on the level of CP in the new taxonomy (Marzano & Kendall, 2007). Cognitive processes are divided into six levels, namely level 1 retrieval, level 2 comprehension, level 3 analysis, level 4 knowledge utilization, level 5 metacognitive, and level 6 self-system. The questions were developed on the material of the nervous system.

Data Analysis

Data were analyzed qualitatively for the content obtained. The aim of this analysis is to achieve concepts that will explain the data and reveal the relationships between these concepts (Yildrim & Şimşek, 2006). As for the stages, the analysis includes grouping data by looking at the average value (Mean) and the frequently occurring value (Modus) for each CP level. After that, the data is interpreted according to the findings and the underlying theory.

RESULTS AND DISCUSSION

Cognitive Process Results

The cognitive process of pre-service science teachers was screened using ten descriptive questions based on six levels of thinking. Before the question, a narrative is presented, which provides the information needed to answer the question. The following narration given in the instrument can be seen in Figure 1.

Pay attention to the following narrative!

In the "Clean Friday" activity in the school environment, Sarah and her group were given the task of cleaning the cactus garden area. While cleaning the cactus garden, Sarah's hand was pricked by a thorn and a wound occurred. Sarah immediately withdrew her hand and pressed the part that was pricked by the thorn and wound. To treat the wound Sarah went to the school healthy unit to look for medicine. In the school healthy unit various ingredients were found that could be used as wound medicine as in Table 1.

Table 1. Materials in school healthy unit

No.	Material	Characteristics
1	Betadine	Antiseptic
2	Honey	Antioxidant
3	Alcohol 70%	Antiseptic
4	Bioplacenton	Antiseptic

Figure 1. Narration on the CP Instrument

After reading the narrative presented, students answered the questions with CP results which can be seen in Table 1. The resulting CP data of pre-service science teachers have a lower tendency at levels 1, 2, and 3 than at levels 4, 5, and 6.

Table 1. CP Ability of Pre-service Science Teachers

Cognitive level	Ability	Mean
1	Knowledge retrieval	35.37
2	Comprehension	10.29
3	Analysis	47.52
4	Knowledge utilization	79.00
5	Metacognitive	73.71
6	Self-system	54.29

Level 1, Knowledge retrieval, is represented by recalling and recognition capabilities. The questions presented in the recalling category are 1. Based on the narrative, what movement did Sarah make when a thorn pierced her hand? 2. Write down the system components involved in movement number 1? Recognition questions are presented in number 3, namely, based on number 2, explain the function of each component correctly. Students' answers to question 1 generally answered not based on understanding the concepts they had learned but only on what they saw. The answer that appears a lot and is wrong for number 1 is as follows: "pulling the arm and pressing the part that was pierced by the thorn." The answer to number two will determine the correct or incorrect answer to question number 3. When students answered correctly the part referred to in number 2, they generally answered correctly for the function in number 3. Of all the research subjects,

only three people answered perfectly. Generally, they need help connecting question and answer number 1 to answer questions 2 and 3.

The ability of representation represents level 2, Comprehension. Question number 4. Explain by drawing how the process of movement number 1 occurs! Most students have yet to be able to answer questions properly. They answered that it was not a body system that worked on reflex movements but only described a cactus tree and a hand pierced by thorns. The answers did not indicate any cognitive ability to answer questions. Several students wrote down the flow of reflexes in chart form instead of pictures, or even many did not answer at all. Various student answers about the reflex movement process can be seen in Figure 2, Figure 3, and Figure 4.
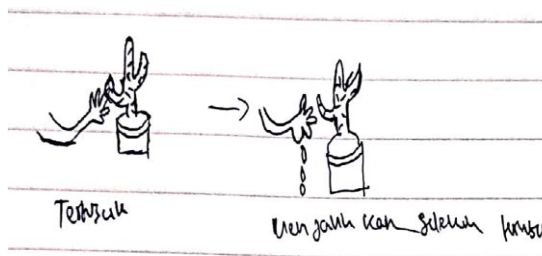

Figure 2. Answers in pictures are based on what students imagine but do not describe their understanding of the concept.
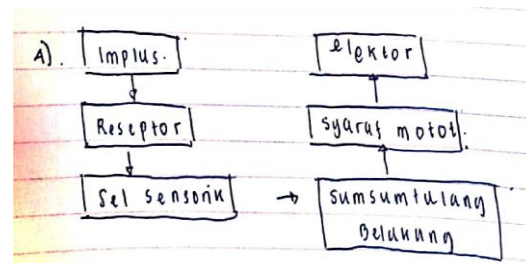

Figure 3. Answers in flowcharts show an understanding of the concept but have not shown an appropriate form of representation.

Figure 4. Answers in the form of pictures of the process of reflex action according to the demands of the questions

Generalizing abilities represent level 3, Analysis—question number 5. Based on number 1, write one important sentence related to the concept! The analytical ability of pre-service science teachers is still relatively low, apart from the average score in Table 1. This can also be seen in the tendency of answers given by students who struggle to generalize the concepts they are learning. The inaccuracy of student answers at this stage also begins with the inaccuracy of answering the previous question. The solution often appears:

"Sarah pulled her hand and pressed the part where the thorns and wounds were pierced."

Level 4, Knowledge Utilization, is represented by decision-making and problem-solving abilities. Questions in the decision-making category, namely 7. Based on Table 1. What material was the most appropriate for Sarah to treat her wound? Explain with reasons! As for the questions for the problem-solving category, namely, 8. What should Sarah and her group do for future activities so that the same incident does not happen again? Write at least 3 suggestions! At this level, most students tend to be able to make decisions to act on the problems they face. This can be seen from the answers to question number 7, with the high occurrence of correct answers with the right reasons. One of the answers obtained was "Betadine, because thorn puncture wounds do not cause hand infection if it is not handled for too long, it is sufficient to use betadine.

In the betadine content, there are also ingredients to kill bacteria and relieve pain. Besides that, at this level, students can also provide suggestions for a future solution so that similar incidents do not happen again. His knowledge is seen to be used to solve the problems he faces. One example of students' suggestions is: "1. Using gloves, 2. Be more careful about completing the task

of cleaning the cactus garden, 3 and using the right tools in cleaning the cactus garden. Tools in cleaning the cactus garden.

Level 5, the Metacognitive system is represented by the capability of specifying learning goals (number 9a), monitoring the execution of knowledge (number 9b), Monitoring Clarity (number 9c), and monitoring accuracy (number 9d). 9a. The following is the scope of the material for the nervous system: 1. Definition, 2. Composition components, 3. Functions of each component, 4. Physiological processes, and 5. disorders of the nervous system. Based on the scope of the material: which ones have been understood? 9b. Which learning process is inappropriate for meeting the learning objectives? 9c. What must be done to compensate for the shortage of points "b"? 9d. Explain the reasons why you want to do point "c"? All aspects of the emergence were very good from the four questions. The appearance of the highest correct answer on the ability to specify learning goals. It can be seen that students are able to state which parts they know or do not know. Based on the analysis of the answers obtained from question 9a. In general, new students understand the function of each component, and they still have

difficulty dealing with physiological processes and disorders of the nervous system. 9b. student answers generally suggest that the visualization of material in learning is made better. 9c. suggestions for better visualization of material, generally, students ask to be presented with three-dimensional media such as videos. 9d. The reasons given generally state that learning that presents material concretely will make it easier to understand.

Level 6, self-system, is represented by beliefs about efficacy. Level 6 ability is measured by question 10: based on your knowledge, explain how confident you are that you can re-explain the nervous system material that you have learned. At the peak level of CP, many self-systems based on Table 1 still have abilities that are below average. This can be seen from the answers that appear, and they generally provide a level of confidence in the form of numbers without explaining their confidence level. Generally, the value of their beliefs is in accordance with the level of the cognitive system they have. Examples of answers that often appear are "Not sure. Because for me, the material on the nervous system is not so easy to learn."

The CP description (Table 1) obtained shows a jump in the ability in the thinking process of science teacher candidates. This condition is contrary to the thought construction process, which states that the ability at the initial stage will be higher than the next stage.

The weak ability of students' CP at levels 1 to 3 indicates a weak basic thinking construction. Retrieval ability is the process of reusing stored knowledge or information by activating it and moving it from long-term to short-term memory. The retrieval ability captured in this study is in the form of recalling ability by giving a label or name to the incident in question and mentioning the nervous system components involved in the movement being asked. Recognition ability is captured by asking about the function of each nervous system component involved. Data comprehension ability is seen in how students use their knowledge in problems that require the ability to synthesize or represent concepts in various forms, such as patterns of associations, formulas, pictures, and so on.

The next CP is an analytical skill that asks students to determine which material is essential and which is not and then use it in the problems they face. The weak condition of CP at this level indicates that there is an inaccuracy in the process they receive in learning. This difficulty occurs if the concept is not

studied in a structured and meaningful way (Kurt, 2013).

The inaccuracy of learning in developing CP is influenced by many factors, both cognitive and non-cognitive factors (Smith & Kelly, 2016). Learning the concept of the nervous system is influenced by many factors; first, there is a paradigm that states that the material of the nervous system is material that is difficult to understand. Second, educators do not understand the material characteristics of the nervous system, so the way of teaching them does not choose the right strategy according to the characteristics of the material. Third, educators only transfer knowledge and do not construct students' understanding well. These three main causes, if left unchecked, will result in inappropriate construction of knowledge in long-term memory and an imbalance in students' thinking processes.

CP ability levels 4 to 6 have shown a pretty good value. The use of knowledge to make decisions and find solutions to specific problems faced at level 4. The ability to think metacognitively at level 5 is their ability to monitor, evaluate, and determine the regulatory processes they face. Then, self-system thinking at CP level 6 indicates that students already have well-managed attitudes, beliefs, and

emotions. Good self-system abilities also show good function in knowledge, cognitive systems, and metacognitive systems.

The high ability of students' CP at levels 4 to 6 is also made possible by many external factors that influence it. These factors include: first, pre-service science teachers are students who already have patterns and independent ways of learning. Second, the learning strategies designed and used by lecturers in managing classes in this PBL course. This learning model requires students to use CP levels 4 to 6 in solving the problems given. PBL presents authentic problem situations that have meaning to students, which can serve as a stepping stone for carrying out investigative and investigative activities (Arends, 2007). Third, the high level of learning objectives to be achieved causes the assignment of cognitive processes to a high level, thereby making students accustomed to thinking at a high level of cognitive processes (Rahmat & Tuzzahra, 2022). Fourth, the ease of technology used to support learning makes it easy for students to find the necessary references. Still, this condition causes students to be unable to store their understanding properly for the long term.

The description of student CP imbalance shows a lack of accuracy in

planning and implementing learning. To improve the quality of students' CP at levels 1 to 3 and maintain levels 4 to 6, it is necessary to improve learning strategies and learning tools to suit the characteristics of the material and students. Learning strategies that pay attention to the characteristics of concept/material representation and involve students actively can improve learning outcomes (Adams & Dewsbury, 2020; Zangerolamo et al., 2020; Cardozo et al., 2020; Gonzales et.al, 2020; Quiroga & Choate, 2019).

CONCLUSION

The Cognitive Process of pre-service science teachers on the nervous system shows the ability to think in cognitive systems that are not yet well formed compared to the ability to believe in metacognitive systems and self-systems. Based on these conditions, developing more appropriate learning strategies to develop the CP of science teacher candidates is still necessary.

SUGGESTION

Based on the findings in the research that has been done, it is better to the learning process should be for educators to pay attention to every system of thinking so that the development of students' CP abilities is solid and balanced. Furthermore, educators can choose, design and carry out learning properly. Additionally, according to the material's characteristics and the students' characteristics so that the learning process can deliver on the expected learning objectives and CP can develop properly.

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