

Conceptual understanding and analysis conceptual difficulties of nervous system: from the perspective of pre-service biology teachers

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Abstract

Keywords:
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The aims of this study were to describe level of conceptual understanding and conceptual difficulties on the nervous system from the perspective of pre-service biology teachers. This research was used cross-sectional research design with a sample of 30 participants was selected randomly. The six essays that were created using the conceptual understanding indicator, and twelve multiple-choice questions that were created in the form of three-tier examinations, and the open questionnaires developed to detect challenging concepts in the nervous system make up the instrument. Data has been analysed using descriptive statistics. Data analysis indicates that the average score of conceptual understanding of pre-service biology teachers is 67.33 belongs to the medium category. For the highest percentage of conceptual understanding indicator is ability to exemplify concepts (86.67%) and the other hand, lower percentage is indicators of ability to connect various concepts (46.67%). The best concept for conceptual understanding especially about sub-matter of structure and function of neurons, central and autonomy nerves. Conversely, for the nervous system concepts that are recognized as challenging, particularly the concepts of physiology, impulse transmission mechanism, and somatic nerve inertia. The lack of conceptual understanding caused by complexity of subject, abundance of terminology, and intangible things. The study is expected to be used mainly for development of various learning methods or media that viewed as suitable for improving conceptual understanding of and reducing conceptual difficulties.

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Introduction

Teaching for conceptual understanding is a primary goal of science education. Conceptual understanding is not automatically acquired when a teacher teaches a material, but is gradually accomplished through learning activities that involve active interactions between teacher and student (Konicek-Moran & Keeley, 2015). The characteristics of science lessons include biology to explore a phenomenon or event and to provide learning activities for learners to clarify, develop or project inquiry, so that the teacher must be able to design and improve the various learning to increase conceptual understanding (Gavalcante et al., 2006). Teacher must be selective in the concept they include in instruction, if they want improve students' conceptual understanding of science. It means that's much content in science should

be used as a guide to provide reasonable level of contents, so it can direct students to build a conceptual understanding, not just remembering what has been learned (Dorothy, 2003).

Conceptual understanding and knowledge level of learning material is a component in realizing the comprehending of the behaviour objectives (Laelasari et al., 2021). Conceptual understanding refers to the level of competence one's has learned in demonstrating concepts, explaining relationships between concepts, and applying concepts that have been understood in problem solving efforts found in daily life (Astuti, 2017; Depdiknas, 2003). Such understanding pertains not only to conceptual definitions but also to one's ability to link concepts with others in a comprehensive way. As for conceptual understanding can be implemented in problem solving that related to the concept (Adhani & Rupa, 2020).

Students' conceptual understanding concerns with the conceptual understanding of teacher. Teachers' conceptual understanding contributes to their performance in organizing learning activities. Teachers should be mastery learning materials as a basis of professional competence. This professionalism can be made possible by ensuring that students are not failing to receive the information presented, make students understand and be able to prevent misconception without pressuring students to be able to understand the material being taught (Russel et al., 2009). Teacher must be able to measure how conceptual understanding of students is achieved through learning activities. In this regard it takes assessment activities to identify the conceptual understanding levels of students using a number of instruments designed in such a way as tests, multi-tier tests or other techniques viewed as suitable for use (Hung Chiu et al., 2007). Conceptual understanding is needed to prevent one's misconception of a concept that has been learned (Irani et al., 2020). The appearance of these misconceptions is due to a person's inability to control them and understand their concepts correctly. Thus comprehensive concept understanding is needed by everyone in assessing the various learning materials, including biology.

Among the concepts in biology that are interesting to examine are those that relate to the nervous system. Nervous system is viewed as a matter of many complex concepts and terms. The nervous system that is part of a coordinate system is categorized as one of the difficult materials to learn (Nisak, 2021). This is enhanced by the results of personal communication with the 12 pre-service biology teachers who have already subscribed to the structure of animals, animal physiology and human anatomy and physiology, which claim that among the biology studied in the three courses, the materials on the nervous system are quite complex because of the many concepts that need to be understood. The condition causes the student learning outcomes become low. Correspond with the research finding, one of the reason that make human physiology difficult to learn because there are many concepts and biological events that cannot be seen with the naked eye, they are too abstract/not visible (Çimer, 2012). Learning difficulties of students in understanding human physiology concepts, including nervous system, are caused by the abstract objects because the physiological process occurs inside the human body (Wardyaningrum & Suyanto, 2019). This indicates that conceptual understanding on the nervous system material is essential for each learner to have, including those of a pre-service biology teachers.

The nervous system material particularly the human nervous system that is presented in human anatomy and physiology is composed of several sub-matter. Generally the sub-material learned by pre-service biology teachers includes the structure, function and type of

neurons, physiology and mechanisms of impulses transmission, the central nerve structure and physiology (brain and spinal cord), physiology and inertia of somatic nerves (spinal and cranial), physiology and inertia of autonomic nerves (sympathetic and parasympathetic), as well as the clinical disorder that relates to the nervous system. Since nerve system material is a fairly complex material, it should be considered more specific about concepts that would be difficult for pre-service biology teacher to relate to the sub-chapter of the learned nervous system. It can help to map concepts in nervous system materials based on the level of difficulty which can be prioritized by a subject's application to strengthen concepts and select methods or learning media that are viewed as convenient for understanding those concepts. It agrees with research results that selection of methods and learning media need to be adapted for students needs and material characteristics to be taught (Andayani et al., 2022; Ibad, 2020).

Conceptual understanding of pre-service biology teacher in nervous system plays a key role in supporting a teacher's professional skills that are necessary for organizing teaching and learning especially in field practice and further away when a teacher is in school. When there is a misconception taught by a teacher, it can affect learners to accept false material concepts, which are due to a lack of material mastery from educators (Novitasari, 2016). If this misconception is maintained then the next concept will be false and become a challenge and difficult in the learning process (Hilarius & Adpriyadi, 2020).

Previous studies have been conducted on pre-service teacher's conceptual understanding analysis of physiological materials, digestive, kinematical, statistical, and algebraic materials that reveal either the difference in the level of conceptual understanding on the indicators analysed or produced by the mapping of concepts on the subject (Adhani & Rupa, 2020; Andayani et al., 2022; Arifin & Aprisal, 2020; Irfan & Anzora, 2017; Sarkity & Sundari, 2020). But research on the conceptual understanding of pre-service biology teacher in nervous system has not been studied, and also on category of conceptual difficulties of nerve system. Based on that it requires further research to unveil and describe the level of conceptual understanding and conceptual difficulties of nerve system by referring to the perspectives of pre-service biology teachers. It is hoped that through this research can provide academic implications and contributions to specifically design a suitable learning scheme for college nervous system in order to promote conceptual understanding.

Method

Researcher use cross-sectional design to measures and describe all variable research at the same time without analysing the effects of any particular treatment (Cohen et al., 2007). The research was conducted by the end of the semester, 2021/2022 academic year. Sample in this study was chosen by simple random sampling technique, each member of the population under study has an equal chance of being selected. As many as 30 pre-service biology teachers has been selected from Biology Education Department of IAIN Kudus, consisting of 8 male and 22 female who have already studied anatomy and human physiology. Researcher develop three kind of instrument in this research: (1) six essay test to measure level of conceptual understanding reviewed from indicator conceptual understanding by referring indicator from Kilpatrick: (a) ability to restate concepts, (b) ability to exemplify concepts (c) ability to connect various concepts, (d) ability to classify objects according to the concept, (e)

ability to present concepts and (f) ability to apply concepts (Kilpatrick, 2002), (2) twelve multiple choice test in form of three-tier test, every question consists of: content tier for measures content knowledge; the reason tier for measures explanatory knowledge; and the confidence tier for measures the strength of conceptual understanding of the respondents (Caleon & Subramaniam, 2010; Dindar & Geban, 2011). This test developed by referring to a subchapter in the nervous system, and (3) questionnaire to find out the conceptual difficulties categories of nerve system material through in the online distributed via Google form. In filling the questionnaire each of them was asked to select two concepts that were deemed difficult related to nervous system material and include the reason. All instruments used were validation by two expert of matter and evaluation.

Data was collected and analysed with the followings step:

a. Data of conceptual understanding

1. Give the test of conceptual understanding to all participant using essay test and three tier-test
2. Processing essay test score
 - a) Take a descriptive analysis for counting the score of each participant in answering the question to know level of conceptual understanding by referring to indicator of conceptual understanding. The essay test points to rubric scoring with the maximum score for each question is 5, so that maximum score for all question is 30.
 - b) Prefiguring percentage levels of conceptual understanding based on score obtained for each indicator.

Counting all of score for each indicator with formula:

$$X = \frac{\text{scores obtained}}{\text{maximum scores}} 100$$

Then processing score into the percentage and further interpreted into the criteria of conceptual understanding (Kartika, 2018).

Table 1. Level of conceptual understanding category

No.	Range Score	Category
1	85 < X ≤ 100	very high
2	70 < X ≤ 85	high
3	55 < X ≤ 70	medium
4	40 < X ≤ 55	low
5	0 < X ≤ 40	very low

3. Processing diagnostic test
 - a) Classified participants' conception (conceptual understanding category) based on diagnostic test outcome.
In order to determine the number of participants who understand concept, researcher classified all participant into 4 group by looking at all possible responses to three-tier test.

Table 2. Category of three-tier test interpretation

Category	Content-tier	Reason-tier	Confident-tier
Understand of concept	T	T	S
Lack of knowledge	T	T	NS
	T	F	NS
	F	T	NS
	F	F	NS
Error	F	T	S
Misconception	T	F	S
	F	F	S

Description:

T = True

F = False

S = Sure

NS = Not Sure

b) Figuring percentage of conceptual understanding

After grouping, the percentage is thereafter made for each group to know the number of participants who understand the conceptual materials of nervous system.

b. Data of conceptual difficulties

1. Give the questionnaire of conceptual understanding to all participant
2. Processing questionnaire in to tabulating data
3. Calculate all of data on the tabulation table and make percentage to know the difficult concept about nervous system from participants viewed.

Results and Discussion

Data of conceptual understanding has been analysed using descriptive statistics. The result shows that conceptual understanding of pre-service biology teachers score averages 66.67 at in medium category. This score of content knowledge.

Table 3. Descriptive analysis of conceptual understanding

N	Minimum score	Maximum score	Mean	Std. Deviation
30	46,67	86,67	67,33	+22,52

Based on conceptual understanding by referring to the number of participant, there are 3 pre-service biology teachers with low category, 18 with medium category, 5 with high category and 4 participants with very high category.

Table 4. Conceptual understanding scores frequency

No	Range Score	Frequency	Category
1	85 < X ≤ 100	4	very high
2	70 < X ≤ 85	5	high
3	55 < X ≤ 70	18	medium
4	40 < X ≤ 55	3	low
5	0 < X ≤ 40	0	very low

The results of the respondents’ conceptual understanding analysis for each indicator can be seen at Table 4. Based on the interpretation of conceptual understanding instruments,

ability to exemplify concept indicator is at the highest category and ability to relate concept indicator is at low category.

Table 5. Conceptual understanding for each indicators

No.	Indicators	Percentage (%)	Category
1.	Ability to restate concepts	73,33	high
2.	Ability to exemplify concept	86,67	very high
3.	Ability to connect various concepts	46,67	low
4.	Ability to classify objects according to the concept	66,67	medium
5.	Ability to present concepts	66,67	medium
6.	Ability to apply concepts	63,33	medium

Besides, determining the level of conceptual understanding based on indicator, this study has also revealed data of participants' conceptual understanding based on the diagnostics test. According to these results, could be known category of participants on any nervous system sub-matter.

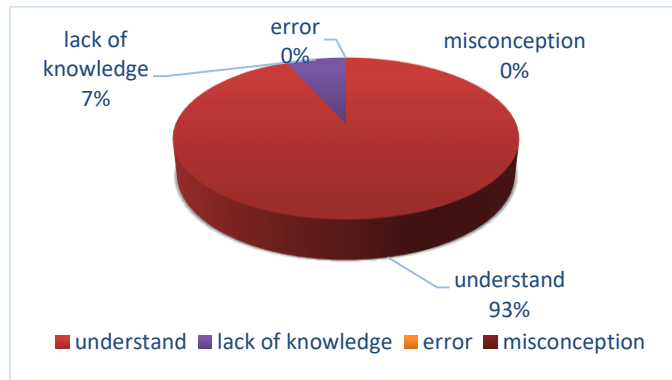


Figure 1. Sub-Matter of Structure and Function of Neuron

Based on **Figure 1** it may be known that the majority of pre-service biology teachers have a conceptual understanding of sub-matter about structure and function of neurons, and only 7% in the category of lack of knowledge.

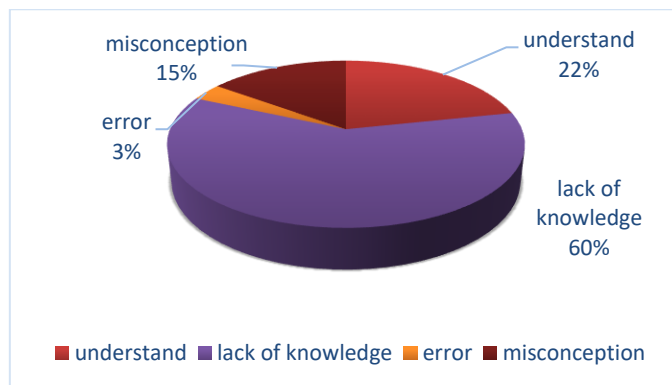


Figure 2. Sub-Matter of Impulses Transmission

Figure 2 inform that the majority of participants were under lack of knowledge, small percentage for misconception and error, while for conceptual understanding category only about 22%. The height of the category lack of knowledge and low for conceptual understanding is due to the complexity of the sub-matter regarding the mechanical transmission of impulses. As for misconception, it is primarily because of the high level of confident on their wrong answer. It may have been due to lack of understanding in material.

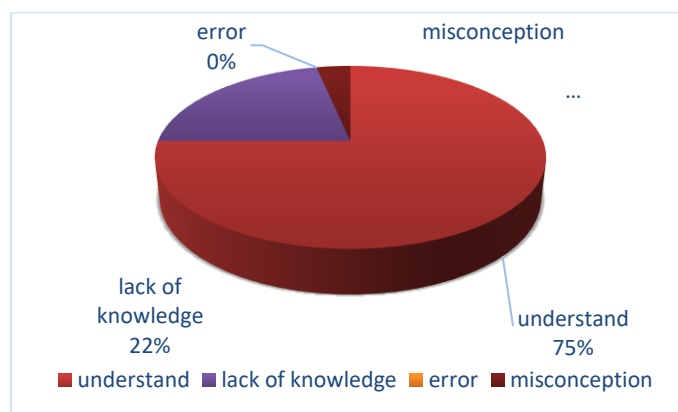


Figure 3. Sub-Matter of Central Nerves (Brain and Spinal Cord)

Based on **Figure 3** it is known that the majority of pre-service biology teachers understand the concept of central nerve sub matter, and only a few participant on the category of lack of knowledge. There was a small percentage of the misconception, due to the incorrect answer to the question of content knowledge and the reason but had a high level of confidence.

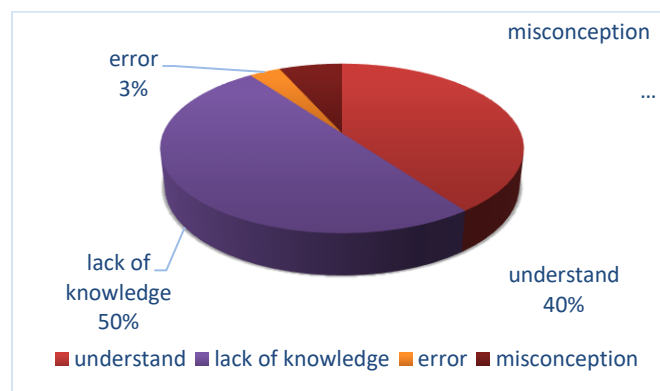


Figure 4. Sub-Matter of Somatic Nerves (Spinal and Cranial)

Based on **Figure 4** it may be known that half of total participants there are at lack of knowledge category in understanding somatic nerve sub-matter that includes physiology and inertia of cranial and spinal nerve. Some 40% of participants are in concept understanding category and there is a small percentage participant has misconception and error.

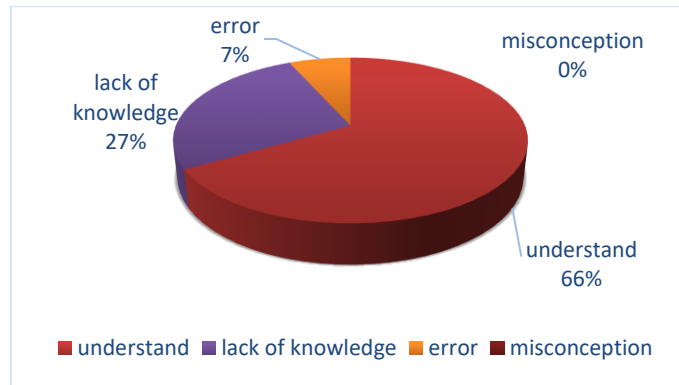


Figure 5. Sub-matter of Autonomic Nerves (Sympathetic and Parasympathetic)

Figure 5 informs that at the sub-matter of the autonomic nerves, more than half of participants were in the conceptual understanding category, and about 27% were within the category of lack of knowledge. There were a few participants who had suffered an error in answering questions but the reason presented was correct.

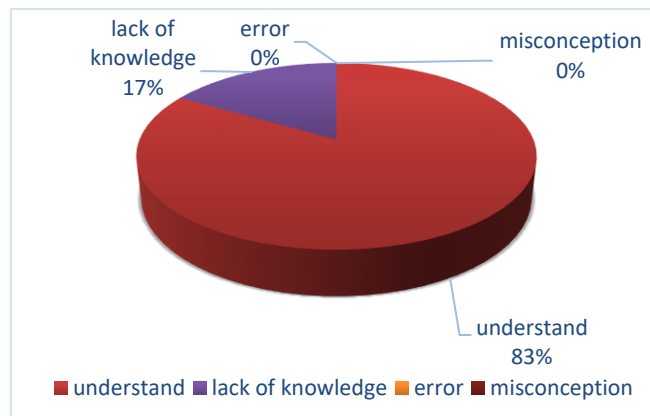


Figure 6. Sub-Matter of Clinical Disorder

Based on **Figure 6** it may be known that on sub matter of clinical disorder most of the participants had already in concept understanding, and only as small was within the category of lack of knowledge. No sign of participants experiencing an error or misconception in these sub-matter.

The information presented in all of figure regarding participants' understanding based on diagnostic tests shows a variety of categories. In some sub-matter such as the structure and function of neurons and clinical disorder, the appearance category lack of knowledge was primarily due to the level of confidence participants “not sure” in answer the question. As for the high conceptual understanding category possible because participants have mastered sub materials that are repeatedly studied in some subjects (such as general biology and animal structure) and previous levels of education. As for the cause of misconception on some nerves system due to the lack of comprehension that presents cognitive conflict. As research reveals that misconception brought by students in the learning process will cause cognitive conflict when allowing new concepts or facts (Kang et al., 2010; Labobar et al., 2017; Ramsburg & Ohlsson, 2016).

The appearance of misconception is also likely relate with the complexity of sub matter, such as misconception participants about mechanisms of transmission impulse,

somatic nerve and central nerve. According to the research that revealed there are several major factors cause misunderstandings, especially characteristics of teaching materials, teachers, students reference books, experience, language and daily textbook (Erman, 2017; Halim et al., 2019; Widiyatmoko & Shimizu, 2018). In this case teachers are required to be able to implement teaching methods that present scientific explanations to students (Neidorf et al., 2020), not only does focus on matter but also takes note of conceptual change from learners to minimize misconception and increase students' understanding of the material being presented (Aykutlu et al., 2015; Moodley & Gaigher, 2019).

In addition, teachers or lecturer may need to conduct interviews with students to identify the student's understanding and detect whether there is any misconception or error thinking. As research reveals that interviews are a diagnostic assessment form to identify students' conceptual understanding, including misconceptions. Through interviews, students' thinking errors can be detected in greater detail (Nitko & Brookhart, 2014), students' conceptual ideas and structures can also be expressed through interviews (Fisher & Frey, 2007; Mintzes et al., 2005). At the college level, conceptual understanding or misconceptions of pre-service biology teacher must be revealed and studied periodically on a variety of subjects. It fits with an explanation that pre-service biology teachers must be targeted for misconception investigations so they are aware of the misconception and have an effort to eradicate it. Awareness of misconception and conceptual understanding is needed by teachers and other practitioners because of the consequences of complexity, even hindering the achievement of 21st-century skills (Resbiantoro et al., 2022).

The research instrument of questionnaires reveal data about conceptual difficulties in nervous system according to the frequency of participant.

Table 6. Conceptual Difficulties of Nervous System Material

No	Conceptual Difficulties	Frequency		Respondent Percentage
		Male	Female	
1	physiology and mechanisms of impulses transmission	7	21	93,3%
2	physiology and inertia of somatic nerves (spinal and cranial)	6	17	76,7%
3	physiology and inertia of autonomic nerves (sympathetic and parasympathetic)	2	4	20%
4	structure and physiology of central nerve (brain and spinal cord)	1	2	10%
5	clinical disorder	1	1	6,67%
6	structure, function and type of neurons	0	0	0%

Based on Table 3 it may be known that the conceptual understanding of pre-service biology teachers in the nervous system material at in medium categories (67,33). This suggests that the vast majority of pre-service biology teachers are viewed as being fairly proficient about the materials of the nervous system. However, there was still a low conceptual understanding of pre-service biology teachers. That is evident from the minimum score obtained from a descriptive analysis of 46.67. So the maximum score (86.67) indicates that there are who have conceptual understanding in the very high category. The data on Table 3 is also enhanced by data details on Table 4 that present category of conceptual understanding by the number of pre-service biology teachers. The score on conceptual understanding represents a person's mental of interpretation concepts of either ideas or integrated from one concept to another and thus develop the conceptual understanding (Susanto, 2015).

A lack of conceptual understanding in learning materials can be caused by some factor such as academic ability, material complexity, retention (person's memory), learning difficulties, or concentration when attending learning. As the opinion suggests that conceptual understanding may be due to a lack of attention to the material being taught (Kartika, 2018). Lack of conceptual understanding also relates to how person's ability to process information or knowledge received either in college or when learning independently from various references (Hindriana, 2014). Academic ability also contributes to affecting learned material mastery that can be used as a basis for gaining greater knowledge.

Based on each conceptual understanding indicator as the data presented at Table 5, it is known that the ability to connect various concepts is an indicator of low category, while the ability to exemplify concept indicator at in very high category. This agrees with research which reveals that the highest conceptual understanding of ability to identify examples and not examples (ability to exemplify concepts) (Adhani & Rupa, 2020; Rahayu & Pujiastuti, 2018) and the lowliest conceptual understanding indicator is the ability to connect various concepts (Adhani & Rupa, 2020).

That result is possible because the ability of a pre-service biology teachers to exemplify concept belongs to a basic concept that is easily understood by everyone. For example, when a respondent is asked to write an example from the sensory neurons, they can largely point to sensory neurons located in the sensory neurons in the retina, sensory neurons in the cochlea or sensory neurons in the olfactory cells in the nose. At the same time, it was also possible for to compare the example of reflex gestures coordinated by spinal cord and to differ from those of the reflexes coordinated by the brain. One is said to understand the concept if it is to define it, to identify and exemplify either a concept or not an example of a concept (Kesumawati, 2008).

As for the ability to connect various concepts that are indicators of low category conceptual understanding, it is possible because connecting one concept with another requires understanding of more than one distinct concept that has a function or character relation to one another. In this case it would require analytical capability which has a higher cognitive level. For example, when are asked to connect comprehensive links between the central nerve function and peripheral nerves involved in either the mechanism for sweating or the management of body temperature, many find it difficult to describe the relationship between the two parts of the nerve. To answer those questions requires an understanding of the

function of the body's temperature and the function of the autonomy nerves (sympathetic and parasympathetic) that govern vasoconstriction and vasodilatation of blood vessels, in turn, connecting the relationship of both concepts to explain why the body percolates after exercise or why the skin becomes pale when the environment is cold. The difficulty in connecting concepts associated with the study of a phenomenon or problems such as the work of the problem could be due to the lack of complex concepts and learners in this case pre-service biology to mastery early concepts or basic concepts (Chiu, 2001).

Based on Table 5 it may also be known that the indicator of ability to restate concepts at in high categories and the other three indicators of the ability to classify objects according to the concept, the ability to present concepts and the ability to apply concepts at in medium categories. The ability to restate concepts refers to the ability of pre-service biology teachers to restate previously communicated concepts (Sari, 2017). For example, when asked about the different kinds of neurons involved in receiving stimulus until they can be interpreted in response, as many of them are able to write in the sequence of neurons: receptors, sensory neurons, connectors, motoric neurons and effector.

The ability to classify objects according to concepts relates to the ability of pre-service biology teachers to categorize an object by specific criteria or categories. Some of these may be measured in relation to the ability of person to categorize the higher functions of the brain according to its parts, the cerebrum, the thalamus and the hypothalamus, the middle brain, and the hind brain composed by cerebellum, Pons and medulla oblongata, each of which has its own function. An indicator of ability to classify is viewed in relation to indicators presents a concept, as one who is able to classify an object will likely be easier to present a concept. Indicators of present concept leading to one's ability to represent/interpret concepts into other forms such as pictures, schemes, tables or graphs (Sari, 2017). This can be seen from the ability of a much pre-service biology teachers to create an organizational scheme of the nervous system and to make sympathetic neural function table and parasympathetic. In this case, when pre-service biology teachers are able to classify the object as conceptual it can easily present it in the form of schematics, tables or charts. That explanation illustrates the reason why the ability to classify objects has scores not so different and falls in the same category as indicators present concepts.

As for the ability to apply concepts relating to the ability of pre-service biology teachers to use those concepts to solve the problems associated with those of everyday life. The understanding indicator of this concept at in medium category. This is possible because most of them were able to give arguments and logical reasons for the problem to be solved by referring to concepts they understood. For example, when a potential biology teacher is asked to analyse the causes of hydrocephalus, most of the child could explain the syndrome as relating to the production of cerebrospinal fluid or to the blockage of the cerebrospinal fluid and to make a conceptual analogy with objects/materials that can be simulated in daily life, such as balloons/vessels that are packed with water or clogged water tap/flow.

Conceptual understanding that have indicators as presented at Table 5 correspond with the conceptual difficulties in the nervous system material as presented at Table 6. Based on Table 6 it may be known that two concepts listed as difficult are those of physiological mechanisms of nerve transmission and physiology and somatic peripheral neural inertia (spinal and cranial nerves). Based on the results of questionnaires it may be known that the

reason for them to choose both concepts as categories of difficult concepts comes primarily from the many concepts and complexity of those associated with the material. In the physiological mechanisms of impulse transmission via nerve cells, many of the concepts that are interconnected and viewed as complex are associated with polarization, depolarization/potential action and repolarization. Impulse transmission through the synaptic involves concepts such as pre-synaptic neurons, post-synaptic neurons, neurotransmitters and other related concepts. As for the conceptual difficulties of physiology and somatic peripheral neural inertia, pre-service biology teachers are faced with the number of cranial nerves and spinal cataloguing, the categorization of nerve types and their functions is considerable, making it difficult for the individual to remember and understand the concept.

In order to increase conceptual understanding viewed as difficult in a material way can be done by various methods such as discussion, bridge building, argument with one another and elaboration, provide correct information, valid reading sources, valid learning media, and appropriate learning models so that there are no misconceptions among students (Fajarwati & Munifah, 2010; Prayitno & Hidayati, 2022). Conceptual understanding can also be enhanced by frequent review of already studied material (Wijayanti, 2016). Conceptual understanding can also be acquired when one is creative and skill full in processing the acquired information and knowledge and is later interpreted back in a form easier to understand and able to implement in daily life (Putri, 2012). Conceptual understanding for pro-service biology teachers is essential to shaping and developing because it can strengthen self-understanding so that it is easier to transpose and explain concepts already had to students and prevent misconceptions (Puk & Stibbards, 2011).

Conclusion

Conceptual understanding of pre-service biology teachers in nervous system material belongs to medium categories. The conceptual understanding indicator of the ability to exemplify concept at in very high categories, while indicators with low categories of ability to connect various concepts. As for the ability to restate concepts in high categories and the other three indicators of the ability to classify objects according to their concepts, ability to present concepts and ability to apply concepts falls in medium categories. Based on diagnostic tests, the highest category of students' conceptual understanding on the sub-matter about structure and function of neurons, autonomic and central nerves. Misconception has been found on sub-matter about mechanisms of impulse transmission, somatic and central nervous, as well as an error thinking on sub-matter of impulse transmission, somatic and autonomic nerves. There are two distinct categories of conceptual difficulties in the material of the nervous system according to perspectives of pre-service biology teachers, particularly concepts of physiology and mechanisms of impulses transmission and also concept of physiology and inertia of somatic nerves (spinal and cranial) that caused by the many concepts and complexity of concepts associated with both materials.

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Credit Authorship Contribution Statement

Iseu Laelasari: conceptualization, methodology, formal analysis, writing original draft, and writing-review & editing. **Nur Wakhidah:** formal analysis, resources and writing-review & editing.

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