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Analysis of Grade XI Students' Misconceptions on Nervous System Material Using Five-Tier Diagnostic Test (5TDT)

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Abstract
The Nervous System is a material in Biology that is abstract and complex, which can lead to misconceptions among students. This study aims to identify the conceptual understanding profile using the Five-Tier Diagnostic Test (5TDT). The analysis includes levels of misconceptions and sources of misconceptions. The research data sources were selected using a purposive sampling technique. The research population consists of a real population, namely all grade XI students of SMA Negeri 3 Semarang, as well as a hypothetical population consisting of individuals with similar characteristics. The results showed that the conceptual understanding profile in the Nervous System of grade XI students' material was still dominated by the lack of knowledge (LK) category. Grade XI students were more likely to experience misconceptions about overgeneralization. The most dominant source of misconceptions came from personal thoughts. Further research is recommended to develop or test the effectiveness of learning models that can improve scientific conception (SC) and reduce lack of knowledge (LK). Furthermore, evaluating the quality and accuracy of learning resources is necessary to minimize the emergence of misconceptions.

Keywords: Five-Tier Diagnostic Test, misconceptions, nervous system

INTRODUCTION

Biology encompasses a broad range of concepts, from the concrete to the abstract, from simple to complex (Banks et al., 2023). Each level of organization, from cells to systems, cannot be understood in isolation. The Nervous System is an abstract and complex biological subject because it involves various interrelated components. This complexity can make it difficult for students to develop a comprehensive understanding. Furthermore, many biological processes cannot be observed directly and therefore require a comprehensive understanding. Consequently, the Nervous System is a subject at risk of giving rise to misconceptions.

Misconceptions are understandings that do not align with prevailing scientific concepts (Inggit et al., 2021; Simatupang & Sudrajat, 2023; Sitorus & Dalimunthe, 2024). Misconceptions often stem from preconceptions formed through everyday experiences and an individual's prior knowledge (Inggit et al., 2021; Majidy, 2025; Rosita et al., 2020; Sitorus & Dalimunthe, 2024). Differences in background knowledge influence how a person receives new information (Lestari & Candramila, 2023; Rahmadani et al., 2022). Furthermore, misconceptions can stem from various inaccurate sources of information, such as online media, teaching materials, and peers (Wahyuningasri & Ambarwati, 2022). If left uncorrected, misconceptions can hinder learning in subsequent materials (Irani et al., 2020). Misconceptions can lead to repeated errors in problem-solving when students hold erroneous concepts (Herliana et al., 2024). High levels of misconceptions are also associated with low conceptual learning achievement. Therefore, systematic identification of misconceptions is crucial.

Identifying misconceptions depends on the learning evaluation system teachers use. Evaluations to detect misconceptions must be designed based on common conceptual errors. Commonly used formative

and summative assessments are not yet capable of specifically identifying misconceptions (Gronlund, 1985). Both assessments focus more on learning feedback and assessing learning outcomes. The lack of diagnostic assessments in schools makes it difficult to identify misconceptions among eleventh-grade students. Aprilla & Fitriani (2024) dan Nugroho et al. (2023) emphasized that educators' limited knowledge influences the way they implement diagnostic assessments.

Furthermore, constraints on infrastructure and data analysis also pose obstacles. As a result, identifying students' conceptual understanding is suboptimal. Diagnostic assessment is an effective evaluation method for identifying misconceptions. Gronlund (1985) states that this instrument is specifically designed to detect conceptual errors experienced by individuals during the learning process. Diagnostic assessment can be conducted through various methods, such as concept maps, interviews, quizzes, and tiered tests. However, each method has advantages and limitations in revealing misconceptions in depth. The 2TDT, 3TDT, and 4TDT instruments still have limitations in distinguishing true understanding from guesses or misinterpretations. To address this issue, the Five-Tier Diagnostic Test (5TDT) is used to differentiate between guessing, false positives, and true understanding (Setiawan & Jaelani, 2021). This instrument consists of five layers: answers, confidence in answers, reasons, confidence in reasons, and learning resources (Inggit et al., 2021; Sitorus & Dalimunthe, 2024). 5TDT adds a special level to uncover the sources of misconceptions, such as from the individual themselves, open materials, informal digital sources, or one's own thinking (Salsabila & Ermawati, 2020).

This study is expected to provide an overview of the development of conceptual understanding based on learning experiences and cognitive development. The results are also expected to serve as a basis for improving more effective Biology learning strategies. Based on this, this study was conducted to identify misunderstandings in the Nervous System material among class XI students at SMA Negeri 3 Semarang using the Five-Tier Diagnostic Test (5TDT).

METHOD

Types of Research and Research Subjects

This study employed a quantitative approach with a quantitative descriptive approach. The sample was determined using a purposive sampling technique. The population of this study includes the real population and the hypothetical population (Daniel, 1990). The real population in this study is all 11th-grade students of SMA Negeri 3 Semarang who have characteristics consistent with the research objectives. Meanwhile, the hypothetical population in this study refers to high school students who have similar characteristics in their understanding of the concept of the Nervous System. The research sample consisted of students in grades XI-4, XI-5, and XI-6 at SMA Negeri 3 Semarang.

Instruments and Data Collection

Data collection used a Five-Tier Diagnostic Test (5TDT). The data collection procedure is carried out through the following stages: 1) conducting preliminary studies and managing research permits; 2) developing, validating, and revising the 5TDT diagnostic instrument; 3) conducting trials and analyzing the instrument's quality; 4) collecting data by administering the 5TDT test to research subjects; and 5) processing data, concluding, and compiling a research report.

Data Analysis Techniques

Data analysis was conducted using descriptive techniques, specifically by processing the expert assessment results to derive a feasibility percentage. Descriptive percentages include presenting data in tables and graphs and calculating average values and percentages. In descriptive percentages, no significance test was conducted because this study did not aim to generalize to the population; therefore, there was no generalization error.

The percentage of misconceptions was calculated using the following formula by Sudijono (1996):

$$P = \frac{F}{N} \text{ x } 100\%$$

Where:

P : Percentage of misconceptions

F : Number of individuals who selected the option

N : Total Number of individuals who took the test

The categories of conceptual understanding by Prodjosantoso et al. (2019)are presented in Table 1, and the percentage categories of misconceptions are presented in Table 2 by Gurel et al. (2015).

Table 1. Conceptual Understanding Category

Tier 1	Tier 2	Tier 3	Tier 4	Category
Correct	Sure	Correct	Sure	Scientific Conception
Correct	Sure	Correct	Not Sure	Lack of Knowledge 1
Correct	Not Sure	Correct	Sure	Lack of Knowledge 2
Correct	Not Sure	Correct	Not Sure	Lack of Knowledge 3
Correct	Sure	Wrong	Sure	False Positive
Correct	Sure	Wrong	Not Sure	Lack of Knowledge 4
Correct	Not Sure	Wrong	Sure	Lack of Knowledge 5
Correct	Not Sure	Wrong	Not Sure	Lack of Knowledge 6
Wrong	Sure	Correct	Sure	False Negative
Wrong	Sure	Correct	Not Sure	Lack of Knowledge 7
Wrong	Not Sure	Correct	Sure	Lack of Knowledge 8
Wrong	Not Sure	Correct	Not Sure	Lack of Knowledge 9
Wrong	Sure	Wrong	Sure	Misconception
Wrong	Sure	Wrong	Not Sure	Lack of Knowledge 10
Wrong	Not Sure	Wrong	Sure	Lack of Knowledge 11
Wrong	Not Sure	Wrong	Not Sure	Lack of Knowledge 12

Table 2. Misconception Percentage Category

Percentage	Category
0% ≥ 30%	Low
31% ≥ 60%	Medium
61% ≥ 100%	High

RESULTS AND DISCUSSION

The analysis of student misconceptions was based on results from the five-level diagnostic test instrument, consisting of 20 questions, completed by class XI students of SMA Negeri 3 Semarang. The respondents were 89 students from classes XI-4, XI-5, and XI-6. The conceptual understanding profile was categorized into five categories: scientific conception (SC), lack of knowledge (LK), false positive (FP), false negative (FN), and misconception (M). These five categories were analyzed across eight Nervous System subtopics: 1) Structure and Function of Neurons; 2) Nature and Transmission of Nerve Impulses; 3) Membrane Potential and Mechanism of Action Potentials; 4) Synapses and Neurotransmitters; 5) Reflex Movement; 6) Nervous System Coordination and Hormones; 7) Interneuron Plasticity and Function; and 8) Nervous System Disorders. The results for the percentage of misconceptions about cell material are shown in Figure 1 below.

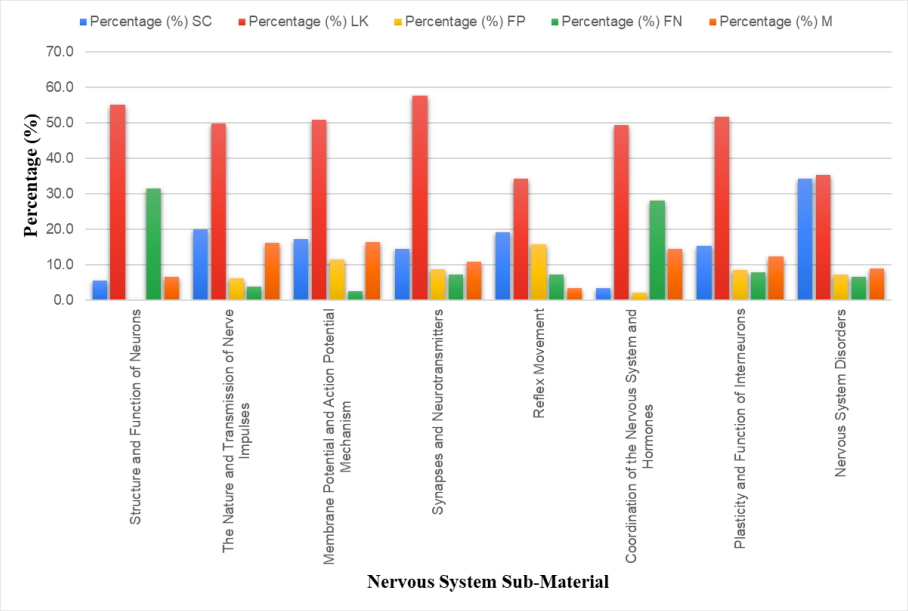

Figure 1. Misconception Profile Analysis Diagram for Each Nervous System Sub-Material in Grade XI Students

The conceptual understanding profile showed that the LK category was the most dominant across almost all Nervous System subtopics. The LK category was highest in the Synapses and Neurotransmitters subtopic, at 57.6%. The high LK category indicates that respondents do not fully understand the working mechanisms of the nervous system. Topics such as synapses, neurotransmitters, and neural plasticity require in-depth conceptual understanding because they involve microscopic processes that are difficult to visualize. A lack of in-depth learning experience can cause respondents to remember terms without fully understanding the mechanisms.

The SC category for 11th-grade students showed relatively low percentages across most sub-topics. The highest percentage was observed in the Nervous System Disorders sub-topic at 34.3%, while the lowest was in the Nervous System and Hormonal Coordination sub-topic at 3.4%. This condition indicates that students still have difficulty understanding concepts that require high-level formal thinking skills. According to Piaget's cognitive development theory, 11th-grade students are at the formal operational stage, but not all individuals develop optimally at this stage. As a result, some students still struggle to understand abstract concepts, especially those related to the complex cause-and-effect relationship between the Nervous System and the Hormonal System.

The FP and FN categories indicate that respondents' conceptual understanding cannot be interpreted solely by whether an answer is correct or incorrect, but is also influenced by their level of confidence in the chosen answer. The data shows that the FP category is dominated by the Reflex Movement sub-topic, at 15.7%. This condition indicates that correct answers are obtained not because of a strong conceptual understanding, but rather through guessing, memorization, or by chance. Respondents are generally familiar with examples of reflex movements, such as withdrawing their hand when touching a hot object or blinking when exposed to bright light. This direct experience helps respondents recognize the correct answer to the question, but an underlying scientific understanding does not always accompany it.

The findings show a fairly high percentage of the FN category in several sub-topics, especially the Neuron Structure and Function sub-topic at 31.5%. The FN category indicates that respondents have a partial understanding of the concept but experience errors in interpreting questions or in connecting the information they have. This condition indicates that some respondents actually have the correct concept, but are not confident in the answer. In line with Suparno (2013) opinion, the level of intuitive thinking can affect an individual's confidence when answering questions. This low level of confidence can be influenced by the lack of conceptual reinforcement during the learning process and the respondents' low academic confidence when faced with complex Nervous System concepts.

According to Prodjosantoso et al., (2019), misconceptions are still at the low level. The highest misconception among eleventh-grade students was found in the sub-topic of Membrane Potential and Action Potential Mechanisms at 21%. Misconceptions in this sub-topic are generally related to incorrect concepts related to the distribution of sodium (Na^+) and potassium (K^+) ions, differences in electrical charge inside and outside the cell membrane, the working mechanism of ion channels, depolarization, repolarization, and hyperpolarization. The many interrelated processes cause students to experience difficulty in building complete conceptual relationships. Based on Piaget's cognitive development theory, not all eleventh-grade students have developed optimally at the formal operational stage, namely the stage of abstract, hypothetical, and analytical thinking abilities. Piaget also argued that the amount of information received does not always determine the improvement of an individual's cognitive development. As a result, when faced with questions that require analysis of action potential mechanisms, students tend to choose answers based on memorization of terms or unscientific intuition. This condition is in line with Suparno (2013) that individuals will spontaneously express ideas before they are objectively and rationally researched.

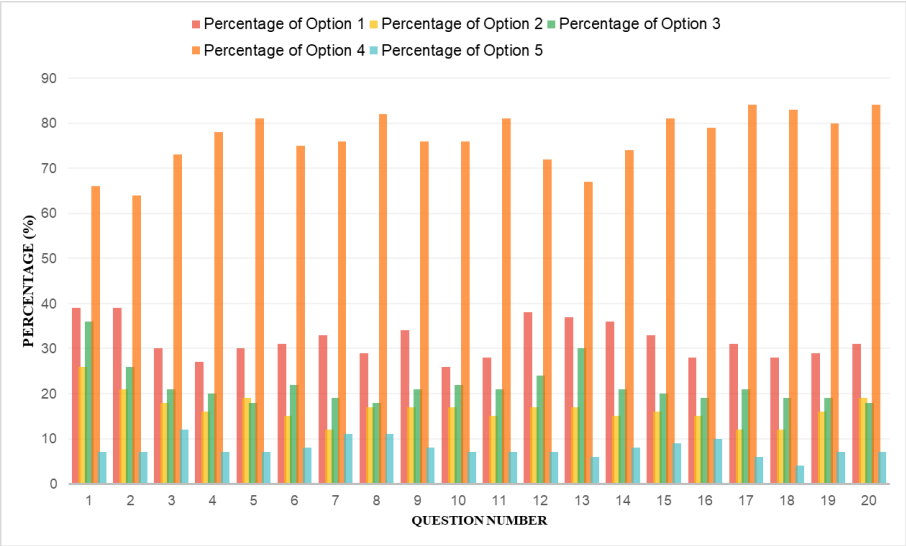

Figure 2. Diagram of Sources of Misconceptions of the Nervous System in Grade XI Students

Data on the sources of misconceptions indicate that errors in understanding Nervous System material are influenced not only by poor mastery of the material and cognitive development, but also by learning experiences and information sources. This study identified sources of misconceptions based on individual preferences, including teaching materials, informal online sources, teacher explanations, personal reflections, and peers. The findings indicate that the highest source of misconceptions was personal reflections, while the lowest was peers. This suggests that misconceptions arise not from mishearing others' information but rather from how individuals interpret experiences and information in their environment.

The diagram shows that many respondents still identified misconceptions stemming from teaching materials. This is because eleventh-grade students still rely on teaching materials as their primary source for understanding the nervous system material. Students tend to accept information in teaching materials at face value without critically evaluating the accuracy of the concepts being taught. Conceptual understanding of the Nervous System material can be erroneous if terminology is used inappropriately or if visualization is inappropriate. As Suparno (2013) noted, textbooks can present distorted concepts to attract readers.

Students' misconceptions from informal online sources tend to be low. The potential for misconceptions to arise from informal online sources is lower among eleventh-grade students, as they rely on teacher explanations and relatively curated textbooks. This aligns with Granic et al. (2020), who found that informal online sources provide a platform for exploring identity while simultaneously learning about

the Nervous System. While this independence is positive for developing an understanding of Nervous System concepts, these sources can also open the door to less credible sources. Students cannot critically evaluate the credibility and accuracy of concepts. Consequently, Nervous System material is acquired without adequate verification, potentially leading to misconceptions.

Regarding the sources of misconceptions, students still found misconceptions in teacher explanations. This finding indicates that teacher explanations remain an influential source in developing understanding of the nervous system concepts. Suparno (2013) also explained various causes of misconceptions due to teachers, such as teachers who lack mastery of Nervous System concepts and pass them on to students. Although teacher explanations generally undergo selection and simplification, understanding can still vary depending on individual abilities.

Suparno, (2013) suggests that misconceptions can arise from incomplete or incorrect reasoning. Some individuals who misinterpret concepts rarely disclose these to their instructors (Suparno, 2013). Suparno (2013) also explained that some instructors rarely discuss or provide opportunities to define concepts in the Nervous System material in their own words. Misconceptions among eleventh-grade students were higher than among students in other grades. These results indicate that respondents construct conceptual understanding independently based on initial interpretations of the information they receive. Respondents are still developing abstract and evaluative thinking skills (in the early formal operational stage), so understandings formed through personal reasoning have not yet been fully scientifically tested. Furthermore, personal reasoning that is not grounded in verification or conceptual discussion can reinforce misconceptions, as individuals tend to maintain their initial beliefs as correct. As a result, independently constructed concepts may deviate from correct scientific concepts.

Suparno (2013) detailed the causes of misconceptions from an individual perspective. He explained that individuals already have initial concepts or preconceptions, which often contain misconceptions. These preconceptions are derived from the individual's experiences as they continually adapt to their surroundings. This aligns with Piaget's theory of cognitive development, which explains how individuals acquire, process, and use information to understand their surroundings. Furthermore, misconceptions are highly likely to occur if an individual's learning abilities and interests are low. Even if the instructor has communicated the Nervous System material correctly or the teaching materials are written in accordance with scientific concepts, the individual may still develop a misconception. As a result, the individual's reasoning is incomplete or even incorrect. The information-processing process becomes less critical and less in-depth, increasing the likelihood of misconceptions when understanding a concept.

Peer discussions are also a source of misconceptions because they are often used to exchange information and clarify the material being studied. This aligns with Vygotsky's opinion that discussion and collaboration with adults and more competent peers play a role in developing an individual's abstract thinking skills. However, if the information shared between peers is not entirely accurate or contains conceptual errors, this can contribute to the formation of misconceptions. Furthermore, each individual has a different level of understanding during peer discussions, which can lead to inaccurate concept transfer. Eleventh-grade students are relatively less dependent on peers as a source of information because teachers and teaching materials still dominate the learning process. Therefore, this difference indicates that the source of misconceptions from peers is influenced not only by social interactions during learning, but also by each individual's learning patterns and academic independence.

Therefore, efforts are needed to minimize the occurrence of misconceptions originating from teaching materials, informal online sources, teacher explanations, personal thoughts, and peers. Improving the quality of teaching materials requires a more accurate, clear, and scientifically advanced presentation of the Nervous System material. Furthermore, students' digital literacy needs to be enhanced so they can select credible and scientific online information sources. Teachers are expected to deliver material more systematically, clarifying concepts that could lead to misunderstandings. Students should also be encouraged to develop critical thinking skills and verify their understanding through personal reflection and discussions with peers. Therefore, the use of resources between teaching materials, educators, and students is expected to minimize the emergence of misconceptions in Nervous System learning.

CONCLUSION

Based on the results of data analysis and discussion, two conclusions were obtained in this study. The conceptual understanding profile for the Nervous System material shows that 11th-grade students are still dominated by the worksheet category across almost all subtopics. The percentage of Scientific Conceptions remains relatively low. The Nervous System Disorders subtopic has the highest percentage of Scientific Conceptions, while the Coordination of the Nervous System and Hormones subtopic has the lowest percentage. The highest source of misconceptions comes from personal thoughts, while the lowest source comes from peers.

Further research is recommended to develop or test the effectiveness of learning models that can improve scientific conception (SC) and reduce lack of knowledge (LK). Furthermore, evaluating the quality and accuracy of learning resources is necessary to minimize the emergence of misconceptions. Future studies could also incorporate other variables, such as learning styles, critical thinking skills, social-emotional development, and cognitive development. This is crucial for a more comprehensive understanding of the factors influencing misconceptions.

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