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Analysis of Student Misconceptions Using the Three-tier Diagnostic Test on Atomic Structure Class X Material at SMA N 1 Lintau Buo

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Abstract

This research is motivated by the number of students who experience misconceptions so that they are not successful in chemistry subjects. This study aims to determine the misconceptions that occur in class X students at SMA N 1 Lintau Buo using a three-tier diagnostic test on atomic structure material. In this study using a qualitative approach (descriptive) method. The subjects of this study were class X students with a total of 108 people. The instruments used are the main instrument (the researcher himself) and supporting instruments, namely the three-tier diagnostic test, interviews, observation and documentation. Data validity testing was carried out by increasing persistence and data triangulation. Furthermore, the data analysis technique uses the classification of student answers from the three-tier diagnostic test, then a percentage is obtained based on the atomic structure sub-matter which is grouped into categories of conceptual understanding, misconceptions and not conceptual understanding. Based on the research that has been done, it can be concluded that the results of the analysis of student misconceptions using the three-tier diagnostic test on class X atomic structure material at SMA N 1 Lintau Buo "are that there are two sub-matter of atomic structure with misconceptions with high criteria, namely in the sub-matter of atomic notation based on the number of protons, neutrons and electrons by 69% and sub-matter of isotopes, isobars and isotones by 62%. For the overall atomic structure sub-matter, the average in the concept understanding category is 36% medium criteria, the misconception category is 55.6% medium criteria and the category does not understand the concept of 8.4% low criteria.

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INTRODUCTION

Chemistry is included in the natural science subject group. Chemistry subjects have characteristics: (1) most of the concepts are abstract, simple, tiered, and structured; (2) Science to solve problems and describe facts and events. Chemistry learning process that is oriented towards the development of science generic skills needs to be developed, so that students can understand that chemistry is a science that is related to everyday life. Chemistry learning that is applied must consider the characteristics of students and the characteristics of chemical materials (Hulyadi et al., 2023; Prayunisa & Mahariyanti, 2022)

The subject matter contained in chemistry is arranged from simple concepts to complex concepts. A complex concept can only be mastered if the underlying concepts have been mastered properly and correctly. Besides the learning success obtained by students, it cannot be denied that there are still other students who experience failure in learning chemistry. (Rina Elvia et al., 2022).

(Hulyadi et al., 2024) state students have difficulty in understanding chemical concepts because of the abstractness of chemical concepts. Concepts that do not match scientific concepts can last a long time and are difficult to correct during formal education because the concept can explain the problem at hand even though it is wrong. These conceptual errors can interfere with the further learning process if not detected as early as possible. Students must be able to master concepts and be able to relate concepts that have been learned. So chemistry learning is very important to emphasize mastery of a concept. Students' prior knowledge tends to clash with scientific concepts. So that between initial knowledge and learning is often not related. This causes concept errors (Sukmawati et al., 2020).

The reality that occurs in schools, many of the students who do not succeed in chemistry subjects because they consider chemistry as a difficult subject. Chemistry is a scary and boring subject. Many factors cause chemistry to be considered a difficult subject, including students' lack of understanding of chemical concepts and many chemical concepts that are abstract. Students sometimes make their own interpretations of the concepts learned as an effort to overcome their learning difficulties which are not necessarily correct according to theory, so that it will have an impact on the emergence of misconceptions. (Lahinda & Tuerah, 2022).

Misconceptions occur because chemistry concepts are abstract and also require a high level of reasoning. The concepts in chemistry are also interrelated, understanding one concept affects other concepts. The learning process of each concept must be mastered correctly before learning other concepts. Students often have difficulty, even failure to integrate new information into previously built cognitive structures. If students' knowledge is insufficient to process new information, they will become confused, reason inaccurately and eventually form misconceptions. This is what then makes the emergence of various concept understandings that are different from each student and allows misconceptions to occur.(Monita, F. A., & Suharto, 2016).

Students already have concepts that are brought as initial knowledge called preconceptions before students learn chemistry concepts. The preconceptions developed by these students are sometimes different from the actual concepts according to chemists. Likewise, each student has a different ability to accept concepts, so it is possible that some of the students have a wrong conception of a concept. Students' mindsets are often not as expected with actual facts. This distorted mindset is called misconception (Astuti et al., 2016; Hulyadi et al., 2023). Misconception is called a misconception because it refers to a concept that is not in accordance with the scientific understanding accepted by experts in the field. The influence of misconceptions that occur in students greatly impacts students' understanding of the material that will be received in the future. In addition, this misconception is often one of the factors that cause student learning outcomes to be not as expected (Rina Elvia et al., 2022).

Chemical misconceptions experienced by students are clearly very detrimental to the smoothness and success of their learning, especially if misconceptions have occurred for a long time and are not detected early, either by the students themselves or the teacher. Chemical concepts are generally taught hierarchically from easy to difficult concepts, from simple to complex concepts, so that if the easy and simple concepts have experienced misconceptions, then further understanding of difficult and complex chemical concepts, students will have more difficulty and experience misunderstanding of concepts (Astuti et al., 2016).

Based on the results of interviews with chemistry teachers at State Senior High School (SMA N) 1 Lintau Buo, information obtained that the problems experienced by students have many misconceptions. This is evidenced during class discussions, students often invert chemical concepts with actual chemical concepts on atomic structure material, for example students

invert expressing the difference between isotopes, isobars and isotones, atomic numbers with mass numbers and other atomic structure sub-materials that are not in accordance with what is conveyed according to experts or actual theories. Based on the results of interviews with students, students generally experience misconceptions if the material is delivered too quickly and is difficult to understand. The material that is considered difficult by students is atomic structure material because of the combination of understanding concepts and mathematical calculations and the method used is only the lecture method, so students tend to have difficulty in the material. This is evidenced by the results of daily tests below the Criteria for Achieving Learning Objectives (KKTP). The results of interviews with chemistry teachers also conveyed that the teacher had not analyzed students' misconceptions on atomic structure material.

There are several ways to detect student misconceptions, one of which is a multiple choice test. The reason for conducting a multiple choice test is because the test can map the weaknesses in each sub-topic of a material (Karim et al., 2022). The three-tier diagnostic test is a form of multiple choice test that can identify misconceptions. The three-tier diagnostic test is a diagnostic test composed of three levels of questions where the first level (one tier) is in the form of multiple choice, the second level (two tier) is in the form of a choice of reasons for choosing answers at the first level, the third level (three tier) is in the form of beliefs from students based on answers at the first and second levels (Kustiarini et al., 2019). The advantage of a three-level multiple choice diagnostic test compared to a regular multiple choice test is that it allows to assess three aspects in one phenomenon (symptom). At the first level students are asked to answer the symptoms that occur, the second level students are asked to explain the reasons for the choices at the first level and the third level students are asked to answer the beliefs of the first level and second level questions. This makes it possible to assess students' concept understanding (Asaefullah et al., 2023).

Misconception analysis can determine the presence or absence of misconceptions in atomic structure material so that this can support student learning outcomes, so it is hoped that teachers can find solutions after it is known that misconceptions occur in students such as changing models, methods or things related to the learning process that can improve student learning outcomes and not the occurrence of misconceptions. Therefore, this research was carried out with the aim of obtaining an analysis of student misconceptions using a three-tier diagnostic test on atomic structure material so that it can be used as a guideline for teachers to teach chemistry for the next chemistry learning process because previous research has not analyzed the misconceptions of chemistry learning specifically for atomic structure material. The difference between this research and the existing ones is that this research uses a three tier diagnostic test and is supported by the results of interviews with students.

This research was conducted with the aim of analyzing the misconceptions experienced by students, then after the analysis was carried out, conclusions were made to find solutions so that low chemistry learning outcomes did not occur, one of which was designing a new learning strategy or model to reduce / prevent misconceptions of atomic structure material / other chemical materials at SMA N 1 Lintau Buo.

METHOD

Type of Research

The type of research used is descriptive qualitative. Qualitative research explains in more detail about what activities or situations are taking place than comparing the effects of certain treatments or explaining about people's attitudes or behavior (Fadli, 2021). Then (Waruwu et al., 2023) define qualitative descriptive research as a strategy for searching for meaning,

understanding, concepts, characteristics, symptoms, and descriptions of a phenomenon that is presented narratively in scientific research.

Time and Place of Research

This research was conducted at SMA N 1 Lintau Buo. This research was conducted in the odd semester of the 2024/2025 school year.

Subjects and Objects of Research

The subjects of this study were class X students of SMA N 1 Lintau Buo with a total of 107 students. The population consists of three classes, then the sampling technique is done randomly. Random Sampling is a technique of taking samples of population members randomly without regard to the strata contained in the population (Arieska et al., 2018). The object of this study is to determine students' misconceptions using a three-tier diagnostic test on atomic structure material.

Research Instruments

There are two instruments in this research, namely the three-tier diagnostic test and interview guidelines. After the preparation of the three-tier diagnostic test, validation was carried out by 3 validators. With the criteria of 1 lecturer at UIN Mahmud Yunus Batusangkar, 2 chemistry teachers at SMA N 1 Lintau Buo, and one of these teachers with a chemistry master's degree. After being declared valid by the validator, the questions were tested on non-samples. Researchers calculated the validity, reliability, distinguishing power and difficulty level of the questions using the SPSS 25 application from the test questions answered by students. Furthermore, the questions that have been calculated from the four calculations above from 27 items, there are 15 items that can be used for research on the sample to find out and analyze student misconceptions on atomic structure material. Interviews were conducted individually. The number of respondents conducted was 30 students. Analysis of interview data is done by organizing data, arranging it into patterns (based on researcher questions), and making conclusions.

Data Collection Techniques

Data collection techniques in this study are observation, interview, three-tier diagnostic test and documentation.

Data Analysis Technique

The data analyzed were the results of student tests on the three-tier diagnostic test on atomic structure material. Analyzing student test results by calculating the value and percentage or the number of students who answered correctly and the number of students who answered incorrectly on the question items, and adjusted to the provisions to distinguish student misconceptions. The purpose of analyzing the data that has been collected from the research sample using the instrument is to make it easier to draw conclusions. In calculating the percentage, the following formula is used (Romadhona et al., 2020) :

$$P = \frac{f}{N \times question\ items} \times 100\%$$

While,

P : Percentage rate (pergroup)
F : Number of students in each group for each problem
N : Number of students used as research subjects

According to (Karim et al., 2022) to determine the misconceptions of students categorized as

conceptual understanding, misconceptions and not conceptual understanding from the results of the three-tier diagnostic test were analyzed using a table of categories of student understanding levels based on the results of the instrument answers.

Table 1. Categories of students' level of understanding based on answers from the three-tier diagnostic test

No	Student Answer Patterns	Comprehension Level Category
1.	Core test answers correct - reasoning correct - confident	Understand the concept
2.	Core test answer correct - reasoning correct -not sure	Does not understand the concept
3.	Core test answer correct - reasoning incorrect -convinced	Misconceptions
4.	Core test answer is correct - reasoning is wrong -not sure	Does not understand the concept
5.	Incorrect core test answer - correct reasoning -convinced	Misconceptions
6.	Incorrect core test answer - correct reasoning - not sure	Does not understand the concept
7.	Incorrect core test answer - incorrect reasoning –confidence	Misconceptions
8.	Incorrect core test answer - incorrect reasoning -not sure	Does not understand the concept

Misconceptions criteria were adjusted based on the following table (Romadhona et al., 2020):

Table 2. Misconceptions Criteria

Criteria	Percentage
High	61%-100%
Medium	31%-60%
Low	0%-30%

RESULTS AND DISCUSSION

This research is a descriptive qualitative research that aims to analyze students' misconceptions using a three-tier diagnostic test on class X atomic structure material at SMA N 1 Lintau Buo. Students' answers to the three-tier diagnostic test are grouped into categories of understanding levels based on the answer patterns, namely, understand the concept, misconceptions and do not understand the concept of 15 items. The following data results were obtained.

Table 3. Categories of Student Answers on Atomic Structure Sub-matter

Question number	Atomic structure sub-matter	Kategori		
		Understand the concept	Misconceptions	Don't understand the concept
1 2 3	The development of the atomic model	38% Medium	57% Medium	5% Low
4 5	Atomic notation based on the number of protons, neutrons and electrons	21% Low	69% High	10% Low
6 7 8 9 10	Isotopes, Isobars and isotones	27% Low	62% High	11% Low

Question number	Atomic structure sub-matter	Kategori		
		Understand the concept	Misconceptions	Don't understand the concept
11 12 13 14	Electron configuration	57% Medium	37% Medium	6% Low
15	Valence electrons	37% Medium	53% Medium	10% Low
	Amount	180	278	42
	Average	36 %	55,6 %	8,4%

Table 3 shows the overall multiple choice three-tier diagnostic test results. Students' concept understanding on atomic structure material with five sub-materials tested was 36%, while for the misconception category was 55.6% and the category did not understand the concept was 8.4%. The largest percentage of the three categories is in the misconception category.

The percentage of misconceptions is 57% in the sub-matter of the development of atomic models. Categorized misconceptions that the core test answers are correct - wrong reasons - sure according to table 1 student answer patterns. The question identified the most student errors in the reason part with answer choice C. Students assume that atoms have charges like raisin bread in the Rutherford atomic model while charges like raisin bread in the atomic model were proposed by J.J Thomson. It should be an atom that has a nucleus and a charge of particles around it, an atomic model like the solar system proposed by Rutherford (Hijratur Rahmi, 2024).

In the concept of the development of atomic models, students experience difficulties where students only memorize and do not understand the concept correctly so that students experience errors in answering these questions. This is in accordance with research conducted by (Herdien & Bahriah, 2024) that students incorrectly answered questions on the concept of atomic theory as much as 59.73% due to students having difficulty in distinguishing various types of atomic models because overall they are almost the same, besides that most chemistry lessons are difficult to understand.

The percentage of misconceptions is 69% in the sub-matter of atomic notation based on the number of protons, neutrons and electrons. It is categorized as misconception that the core test answer is correct-reason wrong-sure. The question identified the most student errors in the reason part with answer choice C. Students assume the atomic number is the same as the number of neutrons. The atomic number should be equal to the number of protons, in the question there are two answers where the atomic number is equal to the number of electrons if the atom is in a neutral state, the element in the question is in a neutral state and there are no ions. The researcher also confirmed the student's answer if there was a reason in option B. In the atomic structure material, the sub-matter of atomic notation based on the number of protons, neutrons and electrons has a high level of misconception due to student answers if the core test answer is correct but the reason is wrong, on the other hand, if the core test answer is wrong but the reason is correct with a certain level of confidence, students consider the answer to the question to be correct. The results of interviews with students also convey material that is difficult to understand, namely protons, neutrons and electrons.

In the concept of atomic notation based on the number of protons, neutrons and electrons, students have difficulty where they often reverse the atomic number with the mass number and then distinguish protons, neutrons and electrons. This is in accordance with research conducted by (Herdien & Bahriah, 2024) that this concept is difficult for students to understand, even though this concept is a basic concept that students must have for the next

level. Students incorrectly answered questions on the concept of atomic notation based on the number of protons, neutrons and electrons as much as 62.86% due to students misunderstanding atomic number with mass number, then atomic number is equal to the number of protons.

The percentage of misconceptions is 62% on the sub-matter of isotopes, isobars and isotones. It is categorized as misconception that the core test answer is wrong - the reason is correct - sure. Students understand the concept but not the principle. Students answer that isotopes are atoms that have the same atomic number but students fill in answers that have the same mass number, the same mass number is a concept in isobars. The real answer is that the pair of elements that are isotopes are $^{27}_{13}$AI dengan $^{28}_{13}$AI. Pairs of elements that have the same atomic number and also the same elemental symbol are the concept of isotopes.

Students who have misconceptions are students who have the right answer but give the wrong reason or have the wrong answer but give the right reason. Students who do not understand the concept are students who have the wrong answer and have the wrong reason (Izza et al., 2021). Misconceptions in one material will have an impact on learning difficulties in other materials, this is because the concepts in chemistry are interrelated with one another. The sub-matter of isotopes, isobars and isotones is the second highest sub-matter of students who experience misconceptions because the sub-matter of determining atomic notation based on the number of protons, neutrons and electrons students experience many misconceptions so that students have difficulty determining isotopes, isobars and isotones.

On the concepts of isotopes, isobars and isotones, students have difficulty where students often reverse expressing these three concepts. This is in accordance with research conducted by Desmaria, L., Eka Putra, R & Inelda, Y. (2019) Misconceptions in isotope, isobar and isoton material amounted to 67% of students reversed the concept. Then the results of observations with students that isotope, isobar and isoton material is material that is difficult to understand, in accordance with research conducted by (Eviota & Liangco, 2020). As many as 58.3% of students find it difficult to compare isotope, isobar and isoton material. Therefore, students experience misconceptions because it is difficult to compare the material.

The percentage of misconceptions is 37% on the electron configuration sub-matter. It is categorized as misconception that the core test answer is wrong - correct reason - sure. In the question, students are wrong in the core question, the atomic number 35 is stated but the answer chosen in option C has an atomic number of 33, the electron configuration of element Br with the actual atomic number is $_{35}$Br = 2.8.18.7. The sum of electron configurations equals the atomic number of an element. The maximum electron configuration rule is 2.8.18.32 starting from the skin K, L, M, N and so on. This research is in accordance with the occurrence of misconceptions in electron configuration material that has been carried out by (Ischak, N.I Domu, S.A., & Najmah, 2023). In the electron configuration sub-concept, students experienced misconceptions as much as 91.83% of 300 students. Of the 300 students, 293 students had misconceptions. Students are not careful when calculating atomic numbers with electron configurations according to the Bohr atomic model.

The percentage of misconceptions is 53% on the valence electron sub-matter. It is categorized as misconception that the core test answer is wrong - true reason - sure. Valence electrons are electrons that are in the outer shell. The concept is that if students understand electron configuration material, it will be easy to determine the valence electrons of an element. In the question, students incorrectly answer the core question, an element has 3 skins (K, L & M) atomic skin and 5 valence electrons (outer skin) the atomic number is skin K the maximum electron is 2, skin L the maximum electron is 8, skin M the maximum electron is 18 but in the

question has been conveyed that the last skin / valence electron is 5. Then the electron configuration is 2.8.5 summed up equal to the atomic number. The real answer is option E.15.

Students consider valence electron material difficult, as many as 53% of students experience misconceptions in this material with a pattern of correct core test answers-false reasons, wrong core test answers correct reasons with a confident level. This research is in line with what has been done by Ischak, N.I Domu, S.A., & Najmah, N. (2023), the percentage of student misconceptions on valence electrons which is a sub-matter of atomic structure is 59% in the moderate category.

Based on the interview results, students experience misconceptions if the material is delivered too quickly and is difficult to understand. The method used is only the lecture method, so students tend to have difficulty in understanding the material. Some students also dislike chemistry subjects.

Misconceptions that students have greatly affect learning outcomes. In chemistry, the concepts learned are interrelated between one concept and another and there are several concepts that are prerequisites for being able to understand the next concept. Thus, if students experience misconceptions in the initial concept, they will experience misconceptions in the next concept and can affect learning outcomes and student achievement (Kamal & Mulhayatiah, 2019).

Students who experience misconceptions have the characteristics of (1) having a wrong conception of the concept, (2) feeling very confident about the correctness of the concept, (3) always trying to maintain their wrong conception. These three characteristics can be used to detect whether the student has misconceptions or not (Utami et al., 2017). In accordance with the literature, students have these misconception characteristics and believe in the truth of the concept, but the concept is not necessarily correct, which results in a wrong conception. Students who experience misconceptions try to maintain their wrong conceptions according to the pattern of answers that students answer on the three-tier diagnostic test questions, the core test answers are true-false reasons or false reasons-true reasons with a certain level of confidence.

Students have different ways of learning and have different levels of understanding. The level of understanding or mastery of a student's knowledge if in accordance with existing concepts then the student is said to have understood the concept or correct, but if the student's understanding is different from the existing concept it can be said that the student has misunderstood the concept or misconception (Djarwo, 2019). The level of student confidence is related to misconceptions because of the suitability of student understanding and scientific understanding (Rokhim et al., 2023)

Misconceptions also occur due to lack of motivation to learn from students, or even no motivation at all. This happens because students don't like or even dislike learning material that they think is quite complicated. So that it causes students to be lazy to receive lessons from teachers at school let alone study alone at home. The result is that students are slow and lagging behind in receiving and understanding the material taught, and eventually there is a misunderstanding of the concepts received by students (Djarwo, 2019).

In this study on the material of atomic structure, the average student who understood the concept was 36%, students who experienced misconceptions were 55.6% and students who did not understand the concept were 8.4%. High level misconceptions are found in two sub-matter of atomic structure, namely atomic notation based on the number of protons, atomic notation based on the number of protons, neutrons and electrons and sub-matter of isotopes, isobars and isotones. In line with research conducted by Hidayat, F.A (2018) based on research conducted, it can be concluded that students who understand the concept on atomic

structure material are 44.03% and students do not understand the concept as much as 55.74% (including students who experience misconceptions). This research is in accordance with what has been done by Fathonah, Y.N (2022) based on research that has been done it can be concluded that students who understand the concept of atomic structure are 34%, students who experience misconceptions are 52% and students who do not understand the concept are 16%. The research is the same as the results of researchers where the level of misconception is higher than understanding the concept or not understanding the concept.

The data above was obtained from the results of the three-tier diagnostic test and supported by the results of the interview. Overcoming misconceptions is not an easy problem, because misconceptions tend to be resistant in students. Some misconceptions become students' belief systems, requiring a variety of strategies to be applied over a long period of time. Cognitive psychologists that there are many ways to help students who construct their knowledge so that misconceptions do not occur, including (a) Provide opportunities to conduct experiments; (b) Provide an expert perspective; (c) Emphasizes conceptual understanding; (d) Encourages classroom dialog; (e) Provide authentic activities, (f) Designing theory construction; (g) Forming a learning community (Omrod, 2018).

The existence of previous misconceptions can hinder the process of receiving new knowledge, this will cause students to continue to make mistakes while learning on the related material. Atomic structure material is basic material that will be related to further chemistry material, so it is important for chemistry teachers to overcome these misconceptions in accordance with the literature above. Providing opportunities to do experiments, teachers provide opportunities for students to do experiments, for example in answering questions to come forward so that if students' conceptions are wrong they can be seen immediately and the teacher immediately corrects them. Emphasizing conceptual understanding, the teacher emphasizes understanding the concept first to students so that students' intuition of the material is not wrong. Encouraging class dialog, the teacher and students discuss the LKPD that has been given in groups so that students understand the concept of the material and no misconceptions occur.

CONCLUSION

Based on the research that has been done, it can be concluded that the results of the analysis of students' misconceptions using the Three-Tier Diagnostic Test on class X atomic structure material at SMA N 1 Lintau Buo are as follows: Misconceptions on the sub-matter of the development of atomic models 57% with moderate criteria. Misconceptions on the sub-matter of atomic notation based on the number of protons, neutrons and electrons 69% with high criteria. Misconceptions in the sub-matter of isotopes, isobars and isotones percentage 62% with high criteria. Misconceptions in the configuration sub-matter 37% with moderate criteria. Misconceptions in the valence electron sub-matter percentage of 53% with moderate criteria. The sub-matter of atomic notation based on the number of protons, neutrons and electrons and the sub-matter of isotopes, isobars and isotones with the highest misconceptions in atomic structure material.

RECOMMENDATIONS

This three-tier diagnostic test can be used by educators as an evaluation of the learning process to analyze misconceptions in class X students at SMA N 1 Lintau Buo which is very valid and effective. Educators can also use the three-tier diagnostic test to analyze misconceptions in other chemistry materials.

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