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Development of A Five-Tier Diagnostic Test Instrument on Atomic Structure Material to Identify Misconceptions of SMA Negeri 2 Medan Students

Makharany Dalimunthe[1*], Anjany Tasya Surabika Br Tarigan[2]

1,2 Chemistry Education Study Program, State University of Medan, Jl. Wilem Iskandar Psr V, Medan Estate, Indonesia

*Correspondinge-mail: *makharanydalimunthe@unimed.ac.id

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Abstract: Development of A Five-Tier Diagnostic Test Instrument on Atomic Structure Material to Identify Misconceptions of SMA Negeri 2 Medan Students. Misconceptions can arise from initial conceptual errors, incorrect relationships between concepts, ideas, or wrong views, therefore it is necessary to carry out a misconception analysis. Five-Tier is a form of test that can diagnose misconceptions which is composed of questions, level of confidence in answers, reasons, level of confidence in reasons, and additional open questions. This study aims to determine the results of the needs analysis, the feasibility level of the Five-Tier instrument, the percentage of misconceptions, and student responses. The subjects in this research were 36 students of grade X MIPA 6 SMA Negeri 2 Medan. The instrument was validated by 5 expert validators, namely 3 chemistry lecturers and 2 chemistry teachers. This research uses the development method (R &D) with a 4D model (Define, Design, Development, and Disseminate). This research shows the needs analysis stated that students needed a Five-Tier diagnostic test instrument, the eligibility level met the qualifications well with an assessment from five validators, the reliability test was 0.68, the percentage of the atomic structure misconception category was 27%, and students responded well with an average of 66.5%.

Keywords: instrument, five-tier, misconception, structure material

Abstrak: Pengembangan Instrumen Tes Diagnostik Five-Tier Pada Materi Struktur Atom Untuk Mengidentifiksasi Miskonsepsi Siswa SMA Negeri 2 Medan. *Miskonsepsi dapat muncul dari kesalahan konsep awal, hubungan yang tidak benar antara konsep, ide, maupun pandangan yang salah maka dari itu perlu dilakukan analisis miskonsepsi. Five-Tier merupakan salah satu bentuk tes yang dapat mendiagnosis miskonsepsi yang tersusun atas pertanyaan, tingkat kepercayaan jawaban, alasan, tingkat kepercayaan alasan, dan pertanyaan terbuka tambahan. Penelitian ini bertujuan untuk mengetahui hasil analisis kebutuhan, tingkat kelayakan instrumen Five-Tier, persentase miskonsepsi, dan respon siswa. Adapun subjek pada penelitian ini adalah* siswa *kelas X MIPA 6 SMA Negeri 2 Medan sebanyak 36 siswa. Instrumen divalidasi oleh 5 validator ahli yaitu 3 dosen kimia dan 2 guru kimia. Penelitian ini menggunakan metode pengembangan (R & D) dengan model 4D (Define, Design, Development, dan Disseminate). Hasil penelitian menunjukkan analisis kebutuhan menyatakan bahwa siswa membutuhan instrumet tes diagnostik Five-Tier, tingkat kelayakan memenuhi kualifikasi baik dengan penilaian dari lima validator, uji coba reliabilitas sebesar 0,68, persentase kategori miskonsepsi Struktur atom sebesar 27%, dan siswa memberi respon baik dengan rata-rata 66,5%.*

Kata kunci: *instrument, five-tier, miskonsepsi, struktur atom*

- **INTRODUCTION**

Law of the Republic of Indonesia Number 14 of 2005 contains that teachers are professional educators who have the main task, one of which is to evaluate students. The evaluation stage is a process of collecting and processing information to see the success rate of the learning process that has been carried out and improve the learning outcomes that are lacking from students (Sholahuddin et al, 2021).

SMA Negeri 2 Medan is one of the schools that has implemented the 2013 curriculum in its learning. Therefore, teachers must have the ability to evaluate concepts that develop in their students. From the results of interviews at the school, teachers still rarely evaluate the level of understanding of the concept of chemical matter in their students.

The obstacle experienced by teachers in conducting evaluations is the limitation in making evaluation instruments to see students' understanding of concepts so that results tend to be obtained only based on quantity rather than quality. Several studies in Indonesia show results that teachers in certain subjects have difficulty developing quality evaluation instruments (Sari et al, 2019).

In fact, learners often have difficulty in understanding various chemical concepts. This is supported by Saragi and Dalimunthe's research, 2022 where the Chemistry subject matter in high school / MA includes chemical reactions and calculations oriented to chemistry and concerns abstract and complex concepts so that many students still find it difficult to understand and master the concept of matter. So, in this case it will be a difficult task for chemistry teachers in schools to provide understanding for their students (Yasthophi &; Soleman, 2019).

One of the chemistry learning topics that is difficult for students to understand is Atomic Structure because it is faced with various elements and symbols that are outlined in the periodic table of elements. In the Atomic Structure table, the classification of elements based on periods and groups is presented (Kusumawardhani et al., 2017). Interviews with chemistry teachers at the school said that students had difficulty distinguishing between groups, periods, and periodic properties.

According to Barke, et al (2009) the conception of learners in chemistry is based on a constructivist approach to learning, i.e. learners build their own cognitive. In keeping with this approach learners generate their meanings based on their backgrounds, attitudes, abilities, and experiences before, during, and after the learning process. Therefore, the concepts they build often suffer from misconceptions. Misconceptions can arise from initial conceptual errors, and incorrect relationships between wrong concepts, ideas, and views (Latifah et al, 2020). It is also said that students experience misconceptions if the mistakes made by students are repeated and after deeper learning, students experience misunderstandings in understanding, interpreting, and implementing a concept (Ikram et al, 2018). Misunderstandings often occur in Atomic Structure material at 36% (Wulan and Sukarmin, 2016). Based on the research results of A'yun et al (2018) using a Three-tier diagnostic test instrument, it was reported that the percentage of students' misconceptions for the sub-concepts of Dalton's atomic theory was 24.85%, Thomson's atomic theory was 27.27%, Rutherford's atomic theory was 45, 45%, Bohr's atomic theory was 39.4, and mechanics' atomic theory was 33.33%. Therefore, identifying student misconceptions in Atomic Structure material is an important thing to do in order to reduce

the quantity of misconceptions (Maharani et al, 2019). One way to identify these misconceptions is to carry out diagnostic tests (Salsabila & Ermawati, 2020)

A diagnostic test is a series of tests used to identify a student's weaknesses. Test results can be used as a reference to ensure proper treatment in accordance with student weaknesses. One of the most effective diagnostic test models is the Five-Tier test instrument. The Five-Tier system is composed of questions, the confidence level of the answers, the reason, the confidence level of reason, and additional open-ended questions. Additional questions on the test are designed to help remove the guesswork from student responses (Bayuni et al, 2018). These additional questions can be in the form of drawing tests, reasoning tests, or other tests according to the needs of each subject (Anam et al., 2019).

Based on the description above, it can be said that in the fifth stage, the Five-Tier diagnostic test can determine the stage of conception of pupils. Fajria and Ermavati (2020) suggest that more information about students' beliefs can be obtained with Five-Tier diagnostic tests. Therefore, it is necessary to measure the level of student understanding of the Atomic Structure material, one of which is by developing a Five-Tier diagnostic test. Thus the teacher can identify the level of student misconceptions about the material.

▪ METHOD

Location and Time of Research

This research was carried out at SMA Negeri 2 Medan, Deli Serdang district, with the research time for odd semester T.P 2022/2023, namely November to March 2023.

Subject and object of research

The subjects in this research were 36 students of class X MIPA 6 SMA Negeri 2 Medan. The object to be measured in this research is the level of misconceptions about Atomic Structure Material.

Research instrument

The instruments used to obtain data in this research were interview sheets for needs analysis, validation instruments, five-tier diagnostic test instruments to identify student misconceptions on atomic structure material, and questionnaire sheets to determine student responses to the five-tier diagnostic test developed.

Research Desain

Development research is an attempt to develop a product so that it can be used effectively (Gay, 1990). This research uses the Research and Development (R&D) method. The model used in this research is the 4D Research Model, as for the steps of the model are:

1. Define

This stage is carried out a literature study to obtain research results that are relevant to the product to be developed. Before conducting research and developing products, researchers must find problems or things that become the background of the research. In the introduction, researchers can conduct literature studies related to misconceptions, five-tier diagnostic tests, and the concept of Atomic Structure material. Then conduct a needs analysis, learner analysis, and concept analysis.

2. Design

Design is done to make a design of the product to be produced. Instrument development is done through the development of questions used by teachers that will be developed into a five-tier instrument. In the question, the first level is a question with three answer choices and one correct answer choice, the second level is the level of confidence in the selected answer, the third level is the choice of reasons for the answer, the fourth level is the level of confidence in the reasons given, and the fifth level is an open question. At this stage, the form of the instrument is determined, the grids are prepared, and the instrument is designed.

3. Development

Development contains the activities of making the design into a product and testing the validity of the product repeatedly until it produces a product that is in accordance with the specifications set by expert validators or practitioners. At this stage, stage I revisions, limited/small-scale trials, and stage II revisions are carried out.

4. Disseminate

The trial was conducted to determine the percentage of misconceptions using the five-tier diagnostic test instrument to be developed. The trial involved all students of class X MIPA 6 Negeri 2 Medan.

Data analysis technique

The initial stage in data analysis is testing the feasibility or validity of the five-tier diagnostic test instrument developed by expert validators, then testing reliability, level of difficulty, discrimination, distractors. The five-tier diagnostic test which has been declared feasible is used to identify students' misconceptions about atomic structure material by referring to the students' conception level categories. Table 1 shows the categories of conception levels possessed by students.

Table 1. Conception level category

No	**Tier to**					**concepti on level**
	1	2	3	4	5	
1	Correct	Y	Correct	Y	(SD/SC) (PD/PC) (MD/MC) (UD/UC) (ND/NC)	SC ASC LK UnC
2	Correct	Y	Correct	TY	(PD/PC) or (MD/MC) or (UD/UC)	LK
3	Correct	TY	Correct	Y		
4	Correct	TY	Correct	TY		
5	Correct	Y	Incorrect	TY		
6	Correct	TY	Incorrect	Y		
7	Incorrect	Y	Correct	TY		
8	Incorrect	TY	Correct	Y		
9	Incorrect	Y	Correct	TY		

10	Incorrect	TY	Correct	TY		
11	Correct	Y	Salah	Y		
12	Incorrect	Y	Correct	Y		
13	Incorrect	Y	Incorrect	TY	(PD/PC) or (MD/MC) or (UD/UC)	NU
14	Incorrect	TY	Incorrect	Y		
15	Incorrect	TY	Incorrect	TY		
16	Incorrect	Y	Incorrect	Y	(MD/MC) or (UD/UC) or (ND/NC)	MSC
17	Not Answered or More than one Answer					UnC

Information : Y = Sure; TY = Not Sure

Table 2. Description of Conception Level

No	**Conception Level Category**		
1	SD/SC	*Scientific drawing/scientific conclusion*	Students can provide images/conclusions that match the concept
2	PD/PC	*Partial drawing/partian conclusion*	Students can provide images/conclusions that do not match the concept
3	MD/MC	*Misconception drawing/misconception Conclusion*	Students provide different images/conclusions from the concept
4	UD/UC	*Undefined drawing/undefined conclusion*	Students provide images/conclusions that are not related to the concept
5	ND/NC	*No drawing/no conclusion*	Students do not provide images/conclusions at all
6	SC	*Scientific conception*	Understand the concept
7	ASC	*Almost scientific conception*	Understand some concepts
8	LK	*Lack of knowledge*	Lack of knowledge
9	UnC	*Un-code*	Inconclusive
10	NU	*No understanding on concept*	Don't understand the concept
11	MSC	*Misconception*	Misconceptions

To analyze the results of student responses, a questionnaire was used in the form of statements with the categories of strongly agree being worth 4, agree being worth 3,

disagree being worth 2, and strongly disagree being worth 1. Student response questionnaires were calculated using the following formula:

$P = n/N \times 100\%$

where :

P = assessment percentage (%)

n = number of scores obtained; N = maximum number of scores

The following is an interpretation of the student response questionnaire to the instrument five-tier can be seen in the following table:

Table 3. Interpretation of Student Response Questionnaire

Criteria value	Percentage (%)	Category
4	76-100	Exellence
3	51-75	Good
2	26-50	Poor
1	0-25	Very poor

▪ RESULT AND DISCUSSION

Data Collection and Literature Study

There are also studies relevant to this research conducted by (Asmalinda, et al, 2019) entitled "Development of Three-Tier Diagnostic Tests and Remedial Alternatives in Grade X High School Chemistry Learning (Study on Atomic Structure Material)", Research conducted by (Rosita, et al, 2020) entitled Development of Five-Tier Newton Laws Test (5TNLT) Instruments to Identify Misconceptions and Causes of Student Misconceptions.

Needs Analysis

Based on the results of interviews that chemistry teachers at SMA Negeri 2 Medan already know what misconceptions are. However, teachers still experience obstacles, one of which is that teachers find it difficult to develop quality test instruments to identify misconceptions.

Analysis of Learners

Based on the analysis of students through interviews with a chemistry teacher, it is known that students in class X MIPA SMA Negeri 2 Medan have a low ability to understand concepts in atomic structure material. There are several influencing factors, namely teacher-centered learning so that students tend to be passive in discovering and learning the concept of atomic structure, and students tend to memorize formulas in learning chemistry causing teachers to have difficulty in identifying students' concept knowledge.

Concept Analysis

At this stage, based on the 2013 curriculum, atomic structure material is studied in class X semester 1 SMA / MA. Submaterials on atomic structure are the development of Dalton's atomic theory and model, the development of Thomson's atomic theory and

model, the development of Rutherford's atomic theory and model, atomic constituent particles, determining atomic number and mass number, determining electron configuration, determining quantum numbers.

Product Description and Design

The questions developed by researchers were 30 questions that were validated to expert validators and corrected according to the suggestions of expert validators, then tested in small groups with a total of 15 students, after which the researchers made revisions before being tested on a wide-scale trial. The broad-scale trial was conducted on 36 students with 20 questions, a reduction was made in the questions because according to the teacher or expert at the school students would not be able to complete 30 questions within 60 minutes so that researchers and teachers agreed to reduce the questions with the same time as the small-scale test. Furthermore, students were asked to provide an assessment of the student response questionnaire on the small-scale trial and the broad-scale trial.

The products produced in this study are test question grids, Five-Tier diagnostic test questions, answer keys, scoring guidelines, and results interpretation guidelines:

1) Preparation of Test Question Lattices

The lattice of questions made is adjusted to the learning achievement indicators adjusted to the syllabus set by SMA Negeri 2 Medan teachers. The components in the Five-Tier diagnostic test question grid consist of question indicators, question categories, question numbers and number of questions.

2) Five-Tier Diagnostic Test Questions

The diagnostic test developed in this study is a Five-Tier diagnostic test question. The Five-Tier diagnostic test is a test in the form of multiple choice with a choice of reasons for choosing an answer and the level of student confidence in choosing an answer or reason, then at the fifth level will be given additional questions to measure the level of student understanding of the material.

3) Five-Tier Diagnostic Test Answer Key

The function of the answer key is as a guide to correcting student answers so that the scores generated by students can be known.

4) Five-Tier Diagnostic Test Scoring Guidelines

The scores obtained after conducting the test are interpreted in the categories of understanding the concept, understanding the concept partially, lack of knowledge, not understanding the concept, and misconceptions on each item. Score 1 is given if the answer choice or reason for choosing is correct and score 0 if the answer choice or reason for choosing is wrong. The level of confidence is high if the student chooses a scale of 4 or 5 or 6. The level of confidence is low if the student chooses a scale of 1 or 2 or 3.

5) Guidelines for Interpretation of Five-Tier Diagnostic Test Results

The function of the result interpretation guidelines is to categorize students into conceptual understanding, partial conceptual understanding, lack of knowledge, no conceptual understanding, and misconceptions.

Product Validation by Experts

At this validation stage, the validator assessed 22 aspects related to the Five-Tier diagnostic test designed. The validator provides an assessment which includes the criteria that the test can be used without revision, the test can be used with little revision, the test can be used with many revisions, and the test is not suitable for use.

Small Scale Trial

The purpose of the small-scale trial in this study is to find out the estimated time and see the extent of students' ability to work on questions, namely from the results of the small-scale trial a lot of class X students chose the answer at the end of the time because they thought the time given was not enough.

Product Analysis and Revision

1) Reliability of Five-Tier Diagnostic Test

The high and low reliability of an instrument is known from the reliability coefficient symbolized by Rxx or r11 (Silitonga, 2014).

$$R11 = \left(\frac{k}{k-1}\right)\left(\frac{S^2-\Sigma pq}{S^2}\right)$$

Where:

R11 = reliability using the KR-20 equation
P = proportion of test takers answering correctly
q = proportion of test takers answering incorrectly (p=1-p)
Σpq = the sum of multiplication between p and q
K = many questions
S = standard deviation or standard deviation is the root of the variance which can be found by the equation
S = √((Σx^2)/N)
N = number of test takers
ΣX^2 = number of deviations from the mean square

The reliability coefficient (r11 arau rxx) is compared with r table on r product moment with α = 0.005, if rcount > rtable then the test is declared reliable.

Based on the test results obtained reliability is 0.68. So it can be concluded that the question has high reliability.

2) Level of Difficulty of the Five-Tier Diagnostic Test

The number that indicates the level of difficulty of a test item is called the item difficulty index (P) which can be calculated by the formula:

$$P=\frac{n}{T}$$

Where:

P = item difficulty index
B = number of participants who answered correctly
T = number of test participants (Silitonga, 2014)

Table 4. Results of Analysis of the Level of Difficulty of the Five-Tier Diagnostic Test

No	Category	question number	amount	Persentase (%)
1	Medium	1,2,3,4,5,6,7,8,10,11,13,14,15,17,18,19	16	80
2	Easy	9,12,12	3	15
3	Hard	20	1	5

The percentage of the test difficulty level is dominated by the medium category, this shows that the test used is good. The best test is a test consisting of questions that have a medium level of difficulty and a small range of difficulty distribution.

3) Differentiating Power of Five-Tier Diagnostic Test

The purpose of the differentiability analysis is to distinguish high ability students from low ability students. The following are the results of the analysis of the differentiating power of the Five-Tier diagnostic test that has been tested on a wide scale.

Table 5. Results of Five-Tier Diagnostic Test Differentiability Analysis

No	Status of Question Item	Item	Amount	Persentase (%)
1	Excellent	1,4,8,10,14,15,16,17	8	40
2	Good	7,13,18	3	15
3	Fair	2,6,12,20	4	20
4	Bad	3,5,9,11,19	5	25

4) Five-Tier Diagnostic Test Distractors

The purpose of distractors on Five-Tier diagnostic tests that have been tested on a wide scale is to trick those who are less able or who do not know to be distinguished from students who are able to answer the questions. If less than 5% of the distractors are chosen by students, the distractors are considered not functioning. Distractors are created to test students' accuracy in answering the correct answer. The instrument tested on a wide scale consisted of 20 questions and each had 5 options consisting of 1 answer option and 4 distractor/distractor options. So, there are 80 distractor options on the test instrument. Interpretation of the results of the Five-Tier diagnostic test distractor analysis in a wide-scale trial showed that 88% of the distractors in the answers could be used or functioned well and 12% of the distractors could not be used or did not function well. Meanwhile, 91% of the distractors in the answer can be used or function well and 9% of the distractors cannot be used or do not function well.

5) Analysis of Student Readability Questionnaires on Five-Tier Diagnostic Tests

In the assessment aspect, student responses are given a score ranging from a score range of one to five. Score five is given if the aspect is very good, score four is given if the aspect is good, score three is given if the aspect is quite good, score two is given if the aspect is not good, score one is given if the aspect is not good.

The average result of students' assessment of the response questionnaire is 73.43%, which means that the Five-Tier diagnostic test instrument is included in the good enough category so that the instrument can be used on a wide-scale trial.

Interpretation of Test Results

Analyze the Five-Tier diagnostic test questions by giving a score of 1 for correct answers and correct reasons, score 0 for wrong answers or wrong reasons. The level of confidence is categorized as high if the student has a scale of 4,5,6 and a low level of confidence if the student has a scale of 1,2,3.

Overall, the percentage of each category of student understanding is obtained, namely Scientific conception (SC), Almost scientific conception (ASC), no understanding on concept (NU), lack of knowledge (LK), un- code (Unc) and

misconceptions (Msc) which includes the concept of atomic structure. The following data is presented in the form of a graph in Figure 1.

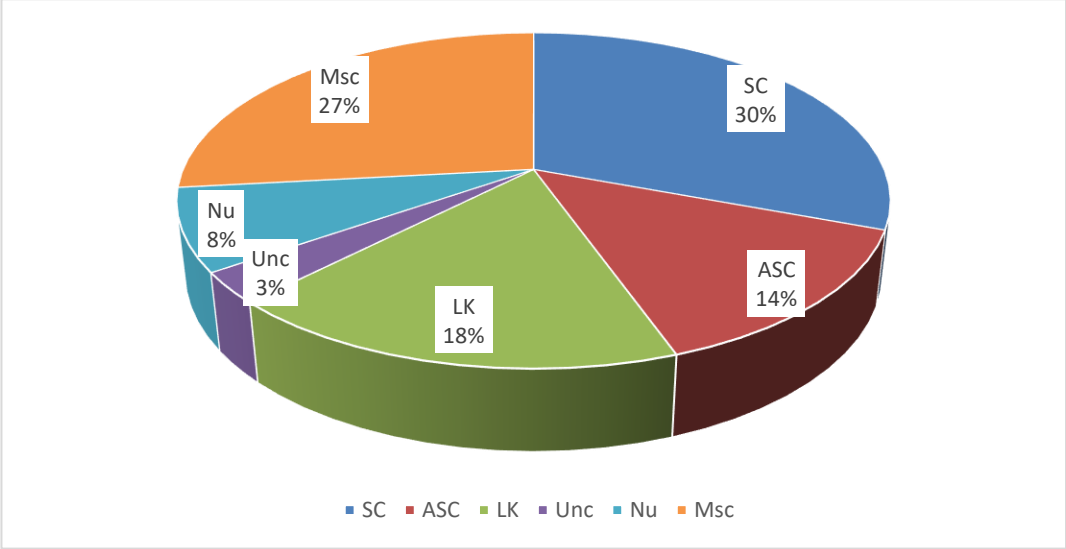

Figure 1. Graph of Misconception Interpretation on Atomic Structure Material

Based on the graph above, it can be seen that the category of understanding the concept occupies the highest percentage, which is 30%. The percentage of the misconception category is 27%, the percentage of the category understanding the concept partially is 14%, the percentage of the category does not understand the concept is 8%, the category of lack of knowledge is 18% and the percentage of the category cannot be concluded is 3%. Misconceptions occurred not only in students who answered incorrectly and with high confidence, but also in students who answered correctly with the wrong reason. This means that students only did (wild guess) or guess with origin (Prabowo, 2022).

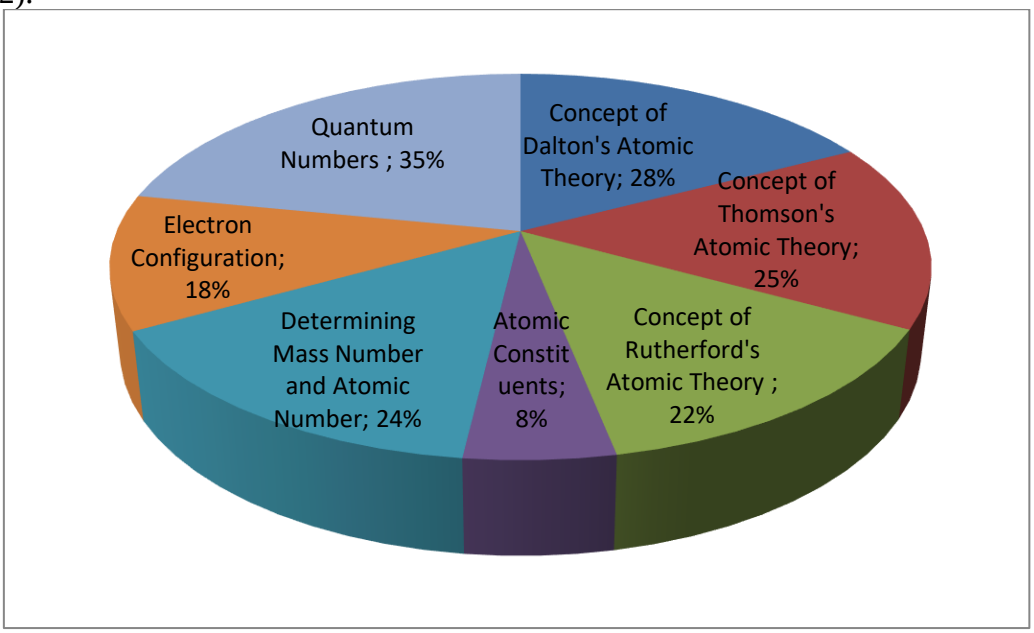

Figure 2. Percentage of Misconception

Based on figure 2, it can be seen that the highest percentage of misconceptions is on the concept of Quantum Numbers by 35% and the lowest percentage is on the concept of Atomic Constituents by 8%. In this research, it was found that the cause of misconceptions was students who liked to guess answers, students had their own reasoning, thoughts or intuition regarding concepts. This is also supported by findings (Ahsin, 2017) which explain that the cause of the highest misconceptions is due to students' own thinking, students who do not understand and remember concepts, students who are still careless in understanding and reading questions. This is in accordance with research (Syahrul, 2015) which states that misconceptions can occur because students are careless in answering questions. Apart from that, teacher explanations are also one of the causes of misconceptions. According to (Suparno, 2013) the teacher's explanation can cause misconceptions. The teacher's explanation or the teacher's way of teaching influences students' understanding of concepts. The cause of misconceptions occurs because of two factors, namely the lack of interest and preparation of students in receiving chemistry learning and the textbook factor, namely because of students' limitations in using the textbook (Roza, 2023)

After conducting a wide-scale trial of the Five-Tier diagnostic test, students were given response questionnaires and assessments of the tests they had taken. There are eleven aspects of questions in the student response questionnaire sheet. Based on the results, the average overall student response was 66.5%, which means the student response to the Five-Tier diagnostic test was in the good category.

▪ CONCLUSION

The results of the research concluded that a five-tier diagnostic test instrument had been produced on atomic structure material to identify misconceptions of class X students at SMA Negeri 2 Medan with a reliability of 0.68. The Five-Tier diagnostic test is reliable in identifying the level of understanding of concepts in atomic structure material. A five-tier diagnostic test instrument is also needed in the learning process to identify misconceptions.

Based on the test results, the percentage of students who experienced misconceptions about the concept of atomic structure was 27%. The results of the analysis of student questionnaire responses showed a positive response to the Five-Tier diagnostic test instrument developed with a percentage of 66.5%, which means that the test instrument used was in the good category.

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