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Analyzing Students' Misconceptions Based on Submicroscopic Level Representation in Elements, Compounds, and Mixtures

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Abstract: The aim of this study is to analyze misconceptions at the submicroscopic level as well as the causal factors of misconceptions in elemental, compound and mixture materials. This research was conducted using descriptive-quantitative method using three-tier diagnostic test and interview. The research subjects were grade IX with 41 students in a junior high school in Malang. The results of this study indicate that 31.0% of students experience misconceptions in determining the concept of atoms, especially for like and unlike atoms in determining elements, compounds and mixtures, 29.0% in the difference in material changes when viewed from the shape of atoms owned, and 27.0% in changes in the constituent particles of elements, compounds and mixtures. The factors causing this misconception are based on the way of learning, misconceptions from teachers, learning methods, initial abilities, and supporting books. The conclusion of this research is that students experience misconceptions that have an impact on their understanding of concepts, especially for the submicroscopic level. The ability to understand the submicroscopic level which is still low causes the need for efforts in reducing the misconceptions that occur.

Keywords: Compound and mixtures; Element; Misconceptions; Submicroscopic level

Introduction

Chemistry is the study of matter and its natural changes and describes the principles of these changes, into related concepts and theories. Chemistry can also be interpreted as a science that seeks answers about what, why and how a phenomenon can occur related to substances, including structure, properties, dynamics, kinetics and energetics involving skills and reasoning (Chang & Overby, 2022). The challenge in studying chemistry exists because of the many abstract concepts that are difficult to understand and require the ability to connect the theory with the application in everyday life (Santos & Arroio, 2016). Abstract chemical concepts can be easier to understand if they involve submicroscopic, macroscopic, and symbolic levels of representation (Gilbert & Treagust, 2009; Johnstone, 1991; Ma'rufah et al., 2022; Treagust et al., 2017).

The representative level understanding that is most difficult for learners to understand is the submicroscopic level. The submicroscopic level is used to explain phenomena at the macroscopic level where it involves the particle level of matter such as molecules, atoms, electron ions, kinetics, structure and movement of particles. Research on the difficulty of understanding submicroscopic representations in chemistry learning

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has been widely conducted including (Akaygun et al., 2019; Derman & Ebenezer, 2020; Allred & Bretz, 2019; Yaman, 2020).

Submicroscopic representations can be in the form of 3-dimensional or 2-dimensional molecular models, drawings or ball and stick models, all of which are abstract concepts. One of the materials that requires students to master the submicroscopic level is an understanding of the concepts of elements, compounds and mixtures. Elements are pure substances that cannot be broken down into other substances through simple chemical reactions, while compounds are substances consisting of two or more elements that are chemically bonded. A mixture, on the other hand, is a compound of two or more substances that are not chemically bound and can be separated by physical methods (Chang & Overby, 2022). The concepts of elements, compounds and mixtures require learners to understand the particulate nature of matter where this concept is an important basis for understanding the concepts of chemistry concepts (Ayas et al., 2010).

The lack of an understanding and complexity of this concept often leads to misconceptions or misconceptions in students. Misconceptions can be defined as understandings that are wrong or not in accordance with correct scientific concepts (Treagust et al., 2017). Misconceptions, or understandings that are not in accordance with correct scientific concepts, often appear in learning elements, compounds, and mixtures. Several studies have shown that students have difficulty in understanding the submicroscopic level of elements, compounds and mixtures as well as the properties of particulate matter (Deleña & Marasigan, 2023; Harrison & Treagust, 2003; Singer et al., 2003; Stojanovska et al., 2012; Chophel, 2022).

Misconceptions are still a problem in the learning process because they can reduce the effectiveness of students' learning and hinder students in understanding new knowledge (Hulyadi et al., 2023; Ningrum et al., 2022; Warsito et al., 2021; Winarni & Syahrial, 2022). These misconceptions can also affect students' understanding of more complex chemical topics in the future, such as chemical reactions, the law of conservation of mass, and the concept of stoichiometry. According to Davidowitz et al. (2010) this submicroscopic level is described by the atomic theory of matter in terms of particles such as electrons, atoms and molecules which generally pertain to the molecular level. This level requires learners to have an abstract view. However, learners often experience misconceptions due to several factors. A mixture, on the other hand, is a compound of two or more substances that are not chemically bound and can be separated by physical methods (Chang & Overby, 2022). The concepts of elements, compounds and mixtures require learners to understand the particulate nature of matter where this concept is an important basis for understanding the concepts of chemistry concepts (Ayas et al., 2010).

Research on the factors that cause the occurrence of misconceptions in students has been widely carried out, including due to factors from supporting books, experiences from teachers, and experiences from students (Kay & Yiin, 2010; Rahayu et al., 2024; Rosyidah et al., 2024), low understanding of prerequisite concepts and lack of chemical representation (Gurcay & Gulbas, 2018), formal thinking ability or abstract thinking ability (Tsitsipis et al., 2012), errors in identifying objects (Akaygun et al., 2014), errors in preconceptions and abstract thinking concepts in the material (Shiddiqi et al., 2024) and acceptance of the initial concept of students.

Acceptance of learners' initial concepts that are wrong in understanding a material can also be a cause of misconceptions that occur (Latifah et al., 2020). Students' knowledge of initial concepts has a relationship with students' ability to solve and investigate a concept. The students' higher level of prior knowledge, the higher the relationship in determining and investigating a concept. When learners are given a concept that contradicts their prior knowledge, cognitive conflict will occur. If learners can resolve their cognitive conflict, misconceptions will not occur and vice versa (Gulacar et al., 2019). Acceptance of this initial concept can also be experienced by students when getting the concept of elements, compounds and mixtures.

One way to identify students' misconceptions is by conducting diagnostic instrument tests (Damsi & Suyanto, 2023). Diagnostic instruments can analyze and describe students' true understanding, including their reasoning ability and reasoning ability and their level of confidence in their answers (Lestari et al., 2021). Many diagnostic instruments have been developed today, for example in the form of tests or in the form of non-tests such as interviews, multiple choice or essays. one of the diagnostics that is suitable for use is a three-tier diagnostic test (Mardiyyaningsih et al., 2023). This is the reason for the author to conduct research with the title "Analyzing Students' Misconceptions Based on Submicroscopic Level Representation in Elements, Compounds, and Mixtures".

This study aims to analyze misconceptions at the submicroscopic level as well as the causal factors of misconceptions in elemental, compound and mixture. Thus, it is hoped that the results of this study can contribute to improvements in chemistry teaching methods at the junior high school level.

Method

This study used descriptive-quantitative method to identify students' misconceptions. The research subjects were 41 respondents of grade IX in one of the junior high schools in Malang City. Data were collected through a diagnostic three-tier diagnostic test and designed to detect misconceptions. In addition to the diagnostic three tier test, interviews were also conducted. The interview was conducted in the form of a semi-structured interview where this interview was intended to dig deeper into the reasons behind the answers chosen by students in the test, so that specific misconceptions could be identified. The interpretation of the test results was described by summarizing all the answers which were then classified based on the criteria for the level of understanding of the concept. The level of concept understanding consists of 3 criteria, namely understanding the concept, not understanding the concept and misconception (Gurel et al., 2015). The research flowchart is likely in Figure 1.

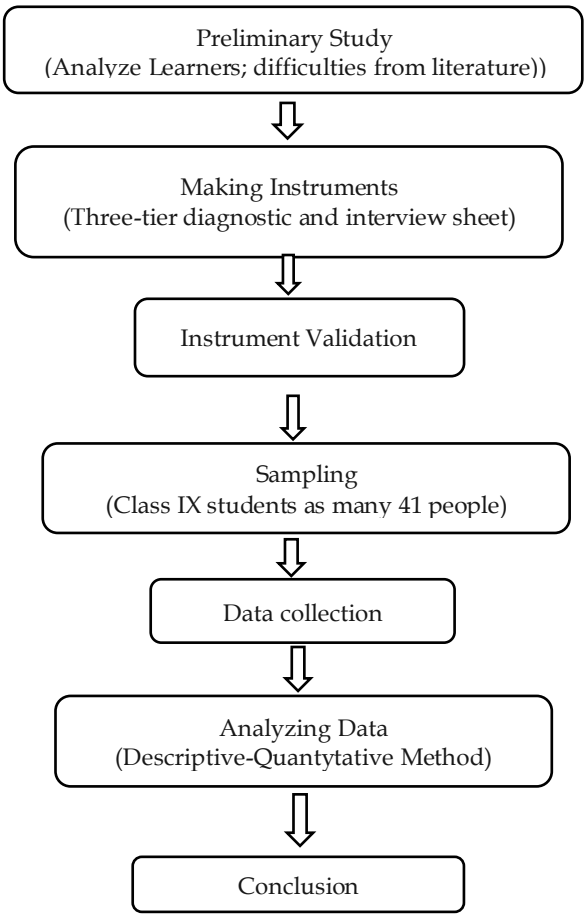

Figure 1. Research flowchart

Result and Discussion

Analysing of Students' Concept Understanding of Element, Compound, and Mixture Materials

The understanding of the concept of determining elements, compounds and mixtures can be known by exploring the concept of students with questions that require students to explain the definition of elements, compounds and mixtures when viewed from the constituent atoms. Elements, compounds and mixture are materials that are introduced to junior high school students. This material requires learners to understand the meaning and application in everyday life. By definition Elements can be defined as pure substances that contain atoms or molecules that are identical to only one type of constituent atom. A compound can also be defined as a pure substance that contains identical molecules with two or more constituent atoms and a mixture is material that has two or more types of molecules (Chang & Overby, 2022).

In General, students have no difficulty in describing the general definitions of elements, compounds and mixtures. This is because almost all textbooks or supporting science books provide these definitions clearly. The problem occurs when students are asked questions about the definition of elements, compounds and mixtures in the form of atomic images. Learners provide varied images to explain the definition of elements, compounds and mixtures. The question for the definition of elements, compounds and mixtures as seen from the constituent atoms can be seen in Figure 2.

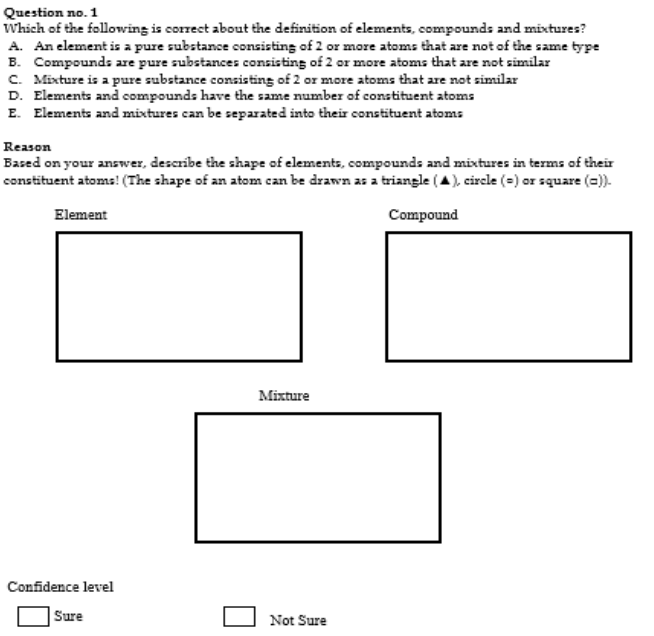

Figure 2. Question to the definition of elements, compounds and mixtures

The addition of the ability to explain the definition of elements, compounds and mixtures when viewed from the image of the constituent atoms is determined by the initial ability of students to atomic material. The ability to draw atomic structures is a sub microscopic level ability that must be possessed by students (Isnaini & Ningrum, 2018; Ma'rufah et al., 2022). When viewed from the answers of students, the submicroscopic level in the atomic structure that they have varies greatly from depicting atomic shapes that are not only round but also triangular or square. When viewed from the results of the students' answers, in addition to the non-uniform shape of the atom in the drawing, also differentiating between non-similar atoms is still an obstacle. In distinguishing similar and dissimilar atoms, many students still have difficulty whether using different sizes or different atomic shapes between each atom.

Submicroscopic level interpretation is indeed a major problem, especially in the interpretation of distinguishing between particles and matter in determining elements, compounds and mixtures (Slapničar et al., 2017; Stains & Talanquer, 2007). This confusion in determining the form of atoms to be used makes the description of the definition of elements, compounds and mixtures often experience misconceptions. Some students' answers in representing the submicroscopic level of the definition of elements, compounds, and mixtures can be grouped into 3 types of answers, namely answers that understand the concept, do not understand the concept and misconceptions. The distribution of the types of answers of students on the concept of understanding of elements, compounds and mixtures can be seen in Figure 3.

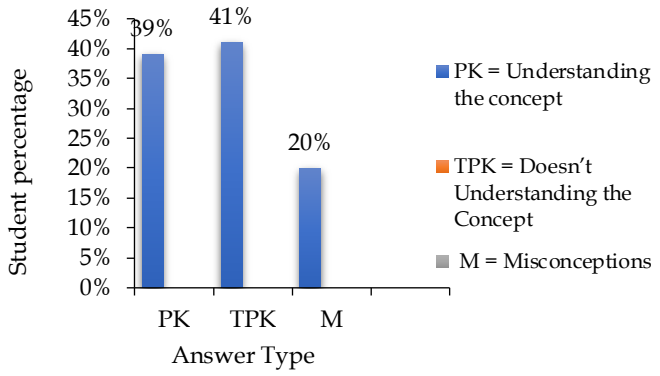

Figure 3. Type of concept understanding for question 1

Interviews are conducted with students who experience misconceptions. misconceptions are obtained from students who answer questions incorrectly but with a large level of confidence in the truth of the answer. interviews are conducted to find out the reasons students answer the question. The interview excerpt is presented as follows (R: Researcher and S: Student).

R: "What is the definition of a compound if it is drawn with its constituent atoms?"
S: "I draw it by arranging 3 atoms that are bonded".
R: "What about the shape of the atoms, for example, similar or dissimilar atoms, does it matter?
S: No effect at all.
R: You are very confident with this answer, what reasoning did you use?
S: Isn't the compound composed of 3 or more atoms. So that's the reason.

Based on the spread of answers, it can be seen that there are 20.0% or 8 learners who experience misconceptions. Misconceptions that occur are many definitions of compounds. This is due to the initial knowledge possessed by students on atomic material. Learners assume that the definition of a compound containing two or more constituent atoms can be described by the same atomic shape with more than one. This concept is wrong because if the shape of the atom is still the same even though there are many atoms, it can be defined as an element not as a compound (Bauer et al., 2019).

In determining elements, compounds and mixtures, question 2 is presented about the composition of the constituent gases of air which is described in molecular form without the chemical formula. The absence of chemical formulas is intended so that learners only determine elements, compounds and mixtures from the submicroscopic level and not from the symbolic. Learners are required to categorize into elements, compounds and mixtures. The distribution of the types of answers of students on the concept of understanding of elements, compounds and mixtures can be seen in Figure 4.

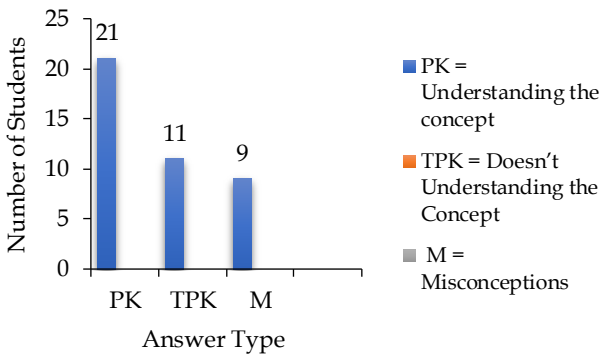

Figure 4. Type of concept understanding for question 2

Based on Figure 4, there are 9 students who had misconceptions on this question. The misconceptions that occurred were due to their lack of understanding in determining elements, compounds and mixtures so that when presented with questions that were only in the

form of molecules, students had difficulty distinguishing between elements, compounds and mixtures. The interview excerpt for question 2 is as follows (R: Researcher and S: Student).

R: Pay attention to picture no. 3 and no. 4, what do they include?
S: Judging from the number of atoms that compose there are 2 means that it can be included in the element.
R: If the color of the atoms is different, does that have an effect?
S: No effect.
R: Are you sure about your answer?
S: Very sure.

Some learners assume that if the molecules of the air composition consist of the same number of atoms then they can be classified into one definition. This is what caused the misconception because even though it has the same number of atoms but the color of the atoms is different, the atoms are not similar so they cannot be included in one definition of an element. The difficulty that students have is because they are not used to facing problems that are directly at the submicroscopic level (Akaygun et al., 2019).

The understanding of the concept of the learners towards the determination of elements, compounds and mixtures continued with the 3rd question by presenting 20 boxes of substance samples of various forms of constituent atoms in each box. The 20 boxes are named alphabetically A to alphabetically T. Learners are asked to group into elements, compounds and mixtures. This grouping is based on how the constituent atoms of these elements, compounds and mixtures are made. The question-3 can be seen in Figure 5 while the distribution of answer types for question 3 can be seen in Figure 6.

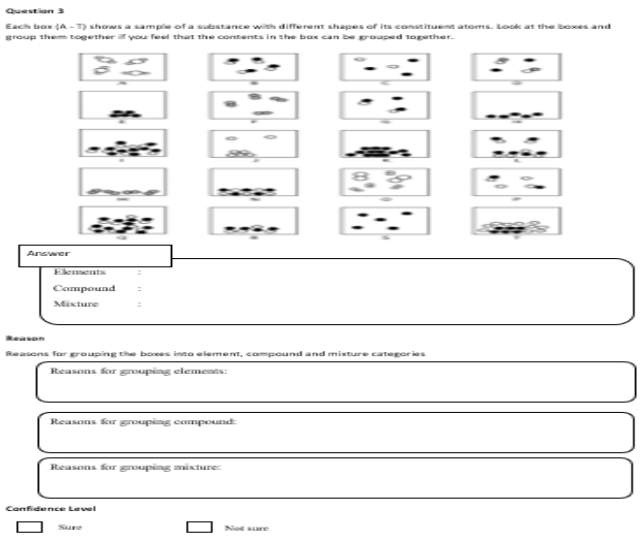

Figure 5. Classification of elements, compounds and mixtures

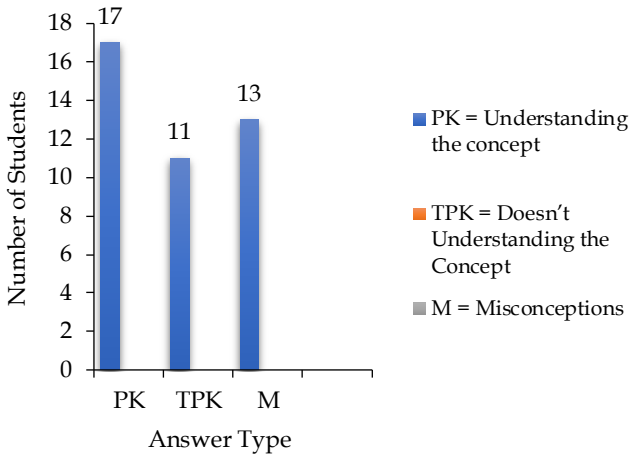

Figure 6. Type of concept understanding for question-3

Based on Figure 6, there is a significant increase in misconceptions for Classification of elements, compounds and mixtures. This improvement is due to the ability of students to classification of elements, compounds and mixtures that are still ambiguous. Learners from the beginning are accustomed to understanding material based only on the macroscopic and symbolic levels so that when faced with the microscopic level, they experience confusion to distinguish between one atom and another (Alighiri et al., 2018). One box that causes many students to experience misconceptions is box O. Learners who experience misconceptions in box O are 7 peoples (Figure 7). The misconception that occurs in students in box O is that students assume that there are 6 molecular shapes that are the same so that they can be classified into elemental forms. But if observed, the size of these 2 molecular shapes is larger when compared to the others. This size difference shows the difference in the constituent atoms so that for box O is not grouped into elements but into mixtures.

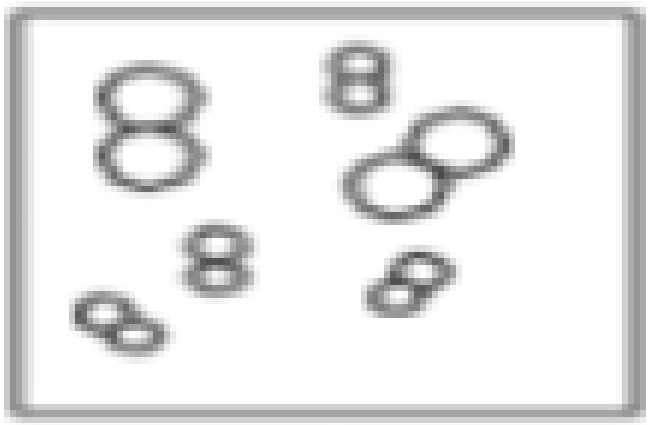

Figure 7. Box O in question-3

The next most common misconception box is box C (Figure 8). Box C presents 5 circles with 2 dark circles and 3 white circles as shown in Figure 6. Learners group the boxes into elements, compounds or mixtures. Many learners experience misconceptions and group into compounds. The Following is an interview excerpt of students who experienced misconceptions in question 3 (R: Researcher, S: Student).

R: Look at box C, which group does it belong to?
S: Compound.
R: Why?
S: Because in box C there are 2 atoms that are not similar.
R: Are you sure about your answer?
S: Sure.

The student's reason for answering like that is because it refers to the definition of a compound where the compound is formed from 2 or more atoms that are not similar. But these compounds are formed if there is an accompanying bond. While, in box C between 1 atom with other atoms do not bind each other. Therefore, it can be said that Box C is included in the mixture because it consists of 2 different elements.

In general, students' submicroscopic level misconceptions in elemental, compound and mixture materials are found in the classification of elements, compounds and mixtures, as well as the application of atomic concepts. The learners have difficulty in translating the classification from the description form into the form of an atomic model. Most Learners still experience confusion about how the shape of the atom will be used to define elements, compounds and mixtures. The next misconception occurs when students are presented with several forms of molecules and then must be grouped into elements, compounds and mixtures. Overall understanding of concepts in element, compound and mixture material can be seen in Table 1.

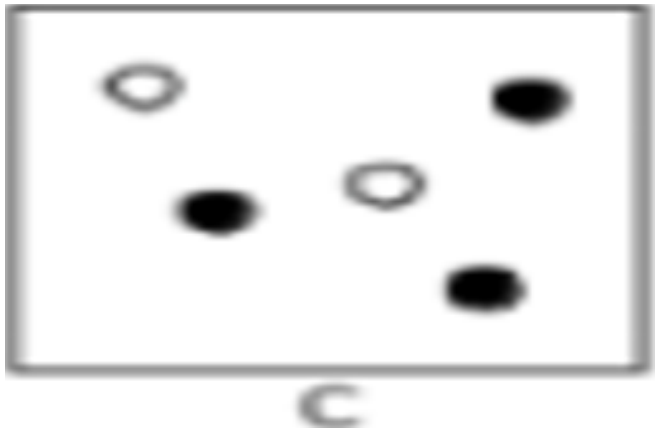

Figure 8. Box C in question-3

Table 1. Result of understanding the concepts of students on the material of elements, compounds and mixtures

Material aspect	Percentage of students (%)		
	Understand the concept	Doesn't understand the concept	Misconceptions
Definition of element, compound and mixture	27.0	48.0	25.0
Determination of elements, compounds and mixtures	38.5	41.0	19.5
Classification of elements, compounds and mixtures	32.0	37.0	31.0
Particle change	42.0	31.0	27.0
Material changes	37.5	33.5	29.0
The concept of application of the atom	46.0	23.0	31.0

Based on Table 1, difficulties in understanding the concepts of elements, compounds and mixtures in one aspect of the material will affect other aspects. Learners who experience misconceptions in the definition aspect of elements, compounds and mixtures will also experience misconceptions about the classification of elements, compounds and mixtures as well as the classification of elements, compounds and mixtures. Misconceptions in this aspect are also influenced by the application aspect of atoms which is a key concept in understanding elemental, compound and mixed materials (Sugiarti & Munfaridah, 2024).

Factors Causing Misconceptions at the Submicroscopic Level and Their Reduction Efforts

Misconceptions are a major problem in learning chemistry factors that cause misconceptions in students come from external factors and internal factors. External factors come from environmental factors that In determining the percentage of factors causing misconceptions, equation 1 is used as follows

$$\% = \frac{\text{Number of answers selected}}{\text{Overall total answer}} \times 100\% \quad (1)$$

The results of the factors causing misconceptions can be seen in Figure 9.

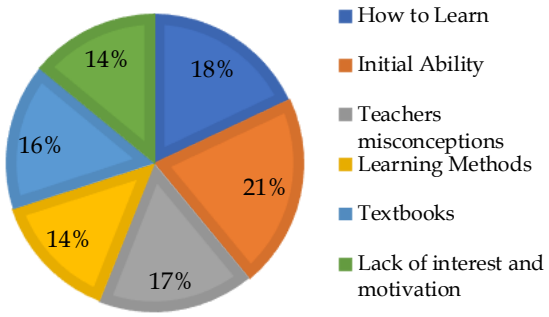

Figure 9. Percentage Diagram of Factors Causing Misconceptions

Based on Figure 9, the initial ability of students is the biggest factor with a percentage of 21.0%. Learners have different abilities in analyzing a concept. Learners with high abilities will be different when compared to the abilities of low learners. The second factor causing misconceptions is supporting books with a percentage of 18.0%. Supporting books are the most important factor in classroom learning. Conceptual errors that are in the supporting book become fatal errors in learning. The initial knowledge of students is first obtained from books and if in the supporting book there is a concept error, it will affect the ability of students to understand a concept.

The next contributing factor to misconceptions is misconceptions from teachers or instructors with a percentage of 17%. Teachers are pioneers in learning and become the first source of knowledge when learning occurs. The role of the teacher in learning is very crucial considering that there are still many students who make the teacher the main source of knowledge. The delivery of the wrong concept of material will result in the ability of students to solve the wrong concept as well.

An effort to overcome misconceptions is to use the right learning strategy. Learning strategies ranging from learning methods, supporting books and correct devices will help students to reduce misconceptions that occur. One of the suitable learning methods used to reduce misconceptions is the ECIRR method. The ECIRR learning model (Elicit, Confront, Identify, Resolve and Reinforce) is a learning model developed by Wenning (2008) and one of the learning models that can support prior knowledge with cognitive conflict strategies for conceptual change. ECIRR model is a model developed from CCM model (Conceptual Change Model) and CEM model (Concept Exchange model). This learning model aims to improve students' alternative concepts into scientific concepts (Effendi et al., 2016; Ningrum et al., 2022).

The ECIRR learning model includes 5 stages, namely elicit, confront, identify, resolve, and reinforce. The elicit stage aims to explore students' prior knowledge. In this phase, the teacher asks an opening question, where students are asked to predict the outcome or state whether they agree or disagree with a given statement related to a particular problem. In the confront phase, students are exposed to situations that challenge their beliefs. The teacher displays inappropriate events to trigger cognitive conflict, so that students are encouraged to formulate opposing views. Then, students compare their prior knowledge with the concepts that appear in the presented phenomenon.

At the Identify stage, after various alternative conceptions are revealed and confronted, the teacher needs to identify, but must be careful not to ignore students' intuition that may produce correct predictions. Teachers also need to prepare arguments to challenge students' beliefs or doubts about the concepts learned. Furthermore, in the resolve stage, teachers need to encourage students to replace alternative conceptions by asking questions, conducting experiments, and interactive demonstrations. In the last stage, namely reinforce, the teacher reinforces the new understanding that students have gained. This reinforcement process needs to be repeated regularly, because changing old understandings into new ones takes time and various situations (Wenning, 2008). If this step is ignored, students have the potential to return to old understandings, so that conceptual errors can continue.

The use of learning media that is more innovative will also help reduce misconceptions held by students. Learning media that can be used to hone the abstract abilities of students can be in the form of videos or in the form of PHET simulations. In addition, other learning media can also use google sites where the use of google sites will make it easier for students to develop abilities (Sari et al., 2022). The use of google sites is an alternative in learning because it is efficient and flexible and can be accessed with various devices such as laptops, smartphones or tablets (Mukti et al., 2020).

Conclusion

Based on the research that has been conducted on elements, compounds and mixtures, it is concluded that the misconception with the largest percentage of 31% is in the concept of applying atomic classification of elements, compounds and mixtures. Overall, misconceptions almost occur in all aspects tested. The main cause of students not being able to see the submicroscopic level in this material is due to the highest factor is from the initial ability of students by 21% and errors from students' supporting books by 18%. This research is only limited in one school with the same

age group so that there is a need for expansion of the research sample so that the results are more accurate. This research is also limited to explaining the causal factors and handling efforts for misconception reduction only. Therefore, it is necessary to develop learning media that are able to reduce students' misconceptions in elemental, compound and mixture materials. One of the learning media that can be developed is the development of learning media based on google sites with the help of the ECIRR model. The development of this learning media in the future is expected as an alternative to be able to reduce the misconceptions experienced by students in elemental, compound and mixture materials.

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Author Contributions

Conceptualization, A.D.A. and U.A.; methodology and design, S. and M.S.; validation, U.A.; formal analysis, investigation, resources and data curation, writing-original draft preparation, A.D.A.; writing-review and editing, M.S. and H.V.S.; supervision, U.A. and S.

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In writing this article, the authors do not have any conflict of interest.

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