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# Johnstone's Levels of Representation in Science Learning

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## Abstrak

Pendidikan IPA, mulai dari sekolah dasar dan sekolah menengah pertama, harus mampu memenuhi tuntutan pemahaman tentang IPA. Pembelajaran IPA SMP merupakan pembelajaran IPA terpadu yang terdiri dari tiga cabang, yaitu biologi, fisika, dan kimia. Memahami kimia secara keseluruhan, yang terdiri dari tiga tingkat representasi, yaitu makroskopis, submikroskopis, dan simbolik, itulah yang dimaksud dengan pembelajaran kimia. Tujuan artikel ini adalah untuk meninjau literatur tentang teori tiga tingkat representasi dan hubungan antara tiga tingkat representasi dalam pembelajaran. Tingkat representasi Johnstone berdampak pada pembelajaran sains dengan mendorong integrasi di berbagai representasi. Penelitian kualitatif ini merupakan penelitian kepustakaan dengan objek utama buku dan literatur lain, seperti jurnal ilmiah dan artikel ilmiah. Istilah merepresentasikan memiliki beberapa arti, antara lain melambangkan, mengingat kembali pikiran melalui gambar atau imajinasi, dan memberikan gambaran. Tingkat representasi mengacu pada penggunaan tiga tingkat representasi untuk mewakili suatu fenomena. Ketiga tingkat representasi tersebut, yaitu tingkat makroskopis, submikroskopis, dan simbolik, saling berhubungan dan berkontribusi terhadap kemampuan pesertadidikmemahami kimia abstrak.
**Kata Kunci:Tingkat Representasi, Pendidikan IPA, Pembelajaran Kimia**

## Abstract

Science education, beginning in elementary and junior high schools, should be able to meet the demand for grasping the notion of science. Junior high school science learning is an integrated science learning that comprises three branches, namely biology, physics, and chemistry. Understanding chemistry as a whole, which comprises three levels of representation, namely macroscopic, submicroscopic, and symbolic, is what learning chemistry entails. The purpose of this article is to review the literature on the three levels of representation theory and the relationship between the three levels of representation in learning. Johnstone's levels of representation have an impact on science learning by encouraging integration across multiple representation. This qualitative research is library research with books and other literature as the main object, such as scientific journals and scientific articles. The term represents has several meanings, including to symbolize, to recall thoughts through images or imagination, and to provide a depiction. Levels of representation refer to the use of three levels of representation to represent a phenomenon. The three levels of representation, namely the macroscopic, submicroscopic, and symbolic levels, are interconnected and contribute to students' ability to understand and comprehend abstract chemistry.
**Keywords: Levels of Representation, Science Education, Chemistry Learning**

## INTRODUCTION

Natural Science is the center of science, and it plays a significant role in the advancement of science and technology. As a result, it should be given special care in order to accelerate its development. Science education, beginning in elementary and junior high schools, should be able to meet the demand for grasping the notion of science. Junior high school scientific learning is an integrated science learning that comprises of three branches, namely biology, physics, and chemistry [1]. Chemistry is a field of science that is taught to junior high pupils. Chemistry is the study of the composition, structure, and behavior of substances or matter from the atomic (microscopic) scale to molecules, as well as changes or transformations and their interactions to form materials found in everyday life [2], [3]

In chemistry learning, which explicitly analyzes material, physical, and chemical qualities, changes in matter, and the energy that accompanies material changes, students' characteristics must be taken into account [4], [5]. This is due to the fact that many pupils continue to struggle with chemical principles [6]–[8]. Learning chemistry entails understanding chemistry as a whole, which includes three levels of representation, namely macroscopic, submicroscopic, and symbolic [7], [9]. The ability of a person to transmit and relate knowledge of macroscopic events, comprehension of the submicroscopic level, and mastery of the symbolic level demonstrates his understanding of chemistry [10], [11].

Today's ability to solve chemical problems directs chemical phenomena at three different levels of representation, namely macroscopic, symbolic, and submicroscopic, and the relationship between one level of representation and another must be explicitly taught [12], [13]. Because the study studies the interaction of properties, properties of atoms to apply knowledge to these three levels of representation. Understanding three levels of chemical representation in depth can help students solve chemical problems by providing explanations regarding structures and processes at the submicroscopic level [14].

Chemistry knowledge and understanding are classified into three levels: macroscopic, symbolic, and microscopic [15], [16]. It is critical to balance the conceptual relationships between the three levels so that students can fully comprehend chemistry. In chemistry, the macroscopic level is associated with observable phenomena such as candle burning, color changes, and so on [17], [18]. Students can learn about the macroscopic level through observation or practicum activities. Computational, pictorial, and algebraic operations are handled at the symbolic level. Teachers can use chemical equations, graphs, reaction mechanisms, formulas, analogies, and numbers at this level [19]. The ability of students to transfer and connect macroscopic phenomena, the submicroscopic world, and symbolic representations demonstrates their understanding of chemistry. One of the higher-order thinking skills is the ability to solve chemistry problems, which requires multiple representation abilities or the ability of students to "move" between various modes of chemical representation. This ability is heavily reliant on submicroscopic representation. The inability to represent submicroscopic aspects can make problem solving involving macroscopic phenomena and symbolic representations difficult. When explaining a color change in a reaction, for example, the teacher can provide the corresponding chemical equation. Color changes can occur at the submicroscopic level as a result of chemical reactions between specific molecules that cannot be observed or observed using the senses. The teacher can use media that describes the related material to show the ongoing process. The purpose of this article is to review the literature on three levels of representation theory and their relationship in learning. By encouraging integration across multiple representations, Johnstone's levels of representation have an effect on science learning.

## METHOD

In this study, the qualitative method is used. A qualitative research approach is a research procedure that generates descriptive data from people in the form of written or spoken words and observed behavior [20]. This qualitative study is a library research with books and other literature as the primary object, such as scientific journals and articles. Library research or library research, namely the collection of library data, or studies carried out to solve a problem based on a critical and in-depth examination of relevant library materials [21]. In this study, the library research procedures were as follows: (1) topic selection, (2) information exploration, (3) research focus determination, (4) data source collection, (5) data source reading, (6) research note taking, (7) research note processing, and (8) report compilation

The data sources used were both primary and secondary, derived from references related to Johnstone's theory of levels of representation and the interaction between Johnstone's three levels of representation. Techniques for collecting data include the use of primary and secondary data documentation in the form of scientific references. The triangulation of sources, both primary and secondary, was used to ensure the data's validity. This qualitative data analysis is inductive, which means that it is based on the data obtained and then develops or becomes a hypothesis. The technique used for analysis is descriptive analysis. The descriptive analysis technique describes Johnstone's levels of representation in science learning in a clear, objective, systematic, analytical, and critical manner.

## RESULT AND DISCUSSION

### Johnstone's Level of Representation Theory

According to the Australian Concise Oxford Dictionary, "representation" means "something that represents another" (means something that represents another) [22]. The term represents has several meanings, including to symbolize, to recall thoughts through images or imagination (to evoke in one's mind through description, portrayal, or imagination), and to provide a depiction (to depict as). The meaning of these terms emphasizes the significance of a representation in helping to describe and symbolize an explanation. Levels of representation refer to the use of representation in various levels of representation to represent a phenomenon [23].

Science and chemistry are both difficult subjects to grasp because many abstract concepts are unfamiliar to students' prior knowledge or mental models. Students' mental models frequently contradict scientific explanations. Although memorizing chemical formulas and facts is important for long-term memory, it does not guarantee that students understand the concept. Students must engage in meaningful learning to construct science/chemistry concepts. Levels of representation can serve as tools to support and facilitate meaningful and/or deep learning for students [24], [25]. Levels of representation are also effective tools for assisting students in developing their scientific knowledge.

As a result, students will find concepts easier to understand and more enjoyable (intelligible, plausible, and fruitful) if they use a variety of representations and learning modes. This is due to the fact that each mode of representation has a distinct communication meaning. Chemical concept representation, like scientific concept representation, is inherently multimodal, involving the use of more than one mode of representation. Macroscopic level, namely chemical phenomena that can be directly observed, including the experiences of students on a daily basis [25], [26]. According to Johnstone, the macroscopic level refers to a chemical phenomenon that can be seen or felt using the five senses [7], [26]. Microscopic symptoms are similar to the way solid salt dissolves in water. To describe a symptom at this level, a microscopic representation is required [24], [26]. The submicroscopic level, that is, when its principles and components are accepted as true and real, a chemical phenomenon that cannot be directly observed is dependent on the atomic theory of matter. The submicroscopic level of matter is described by the atomic theory of matter in terms of particles such as electrons, atoms, and molecules, which are generally related to the molecular level [27]. Students frequently form misconceptions as a result of this representation. This is due to their limited understanding of how to make an imitation of something real a powerful tool in developing mental models of chemical phenomena [26]. While the symbolic level, which includes models, pictures, algebra, and computational forms, is a representation of various chemical phenomena [26]. Furthermore, the symbolic level is a level that represents the chemical material's form in the form of a formula or reaction equation [28], [29].

The three levels of representation are translated into the macroscopic level, submicroscopic level, and symbolic level, which can be explained as follows. (1) macroscopic level, there are descriptions of all chemical substances, changes, and reactions that can be observed with the senses. These include matter properties or mass characteristics such as odor, color, mass, temperature, and reactivity that result from the collective interaction of millions of elementary particles. Macroscopic discussions are frequently characterized by detailed descriptions and observations; (2) submicroscopic level is a representation of a material based on its particle nature. This theory holds that matter is made up of extremely small particles (atoms, ions, and molecules) that are invisible to the naked eye. all particulate matter that is invisible under a light microscope, from large macromolecules like DNA to as small as an atomic nucleus or an electron. This level of discussion includes explanations based on theories, models, and laws, such as employing kinetic molecular theory to explain the proportion of gas volumes to absolute temperatures observed by students in laboratory experiments; and (3) symbolic level, in chemistry, this includes a wide range of image and algebraic representations, symbols, and mathematical relationships. Common examples include chemical reaction equations and chemical symbols. At the symbolic level, to make abstract concepts more concrete, various molecular models are used, allowing them to be manipulated both physically and mentally. [30], [31].

The chemical representation levels are classified as macroscopic representation levels, submicroscopic representation levels, and symbolic representation levels [32], [33]. The macroscopic level of representation is a chemical representation obtained through direct or indirect observations of a phenomenon visible and perceptible to the five senses (sensory level). Observations can be gathered from everyday life, actual laboratory investigations, field studies, or simulations. For example, when a chemical reaction occurs, changes in color, temperature, pH of the solution, the formation of gases, and precipitates can be observed. A student can present the findings of observations or laboratory activities in a variety of ways, including written reports, discussions, oral presentations, vee diagrams, graphs, and so forth. The macroscopic level representation is descriptive; however, students' ability to represent the macroscopic level requires guidance so that they can focus on what aspects are most important to observe and represent based on the observed phenomena.

The submicroscopic level of representation is a chemical representation that explains the structure and processes of macroscopic phenomena observed at the particle (atomic/molecular) level. The term submicroscopic refers to a level of size representation that is smaller than the macroscopic level. Based on the particular theory of matter, the submicroscopic level of representation is used to explain macroscopic phenomena in terms of particle motion, such as electron, molecule, and atom motion. These submicroscopic entities do exist, but they are so small that they cannot be seen. The ability to imagine and visualize is required for submicroscopic operations. At this level, modes of representation can range from simple to using computer technology, namely using words (verbal), diagrams/pictures, two-dimensional models, and three-dimensional models both still and moving (in the form of animation). Qualitative and quantitative chemical representations are examples of symbolic representations., such as chemical formulas, reaction equations, stoichiometry, mathematical calculations, diagrams, and pictures. Symbolic representation serves as the language of chemical equations, so grammatical rules must be followed [34].

The symbolic representation level includes all qualitative abstractions used to present each item at the submicroscopic level. These abstractions serve as submicroscopic entity shorthands as well as quantitative indicators of how much of each type of item is presented at each level. Chemical representation levels should not be confused with the term representation, which is generally used to refer to the symbolic representation of chemical phenomena, including explanatory tools. [27], [35]. The theory of molecular kinetics related to particle motion, such as the tendency for a constant number of chemical species to move, collide with each other, ineffective collisions, and fail to produce a reaction, cannot be represented symbolically. The explanation of chemical phenomena used for this is frequently based on the behavior of submicroscopic particles, which is shownsymbolically [27], [36]. Considering the problems discussed above, the three levels of chemical representation play a critical role in solving chemical problems, beginning with how to plan and carry out problem-solving activities. Because, for example, if the problem of chemical reactions is only solved with one or two levels of chemical representation, or if three levels of representation are taught separately, it results in a lack of students' ability to understand concepts in problem solving, and, ironically, it creates misconceptions.

**Relationship between Johnstone's Levels of Representation**

Chemical phenomena can be explained by three different levels of representation: macroscopic, submicroscopic, and symbolic [26]. Figure 1 depicts each Johnstone's levels of representation.

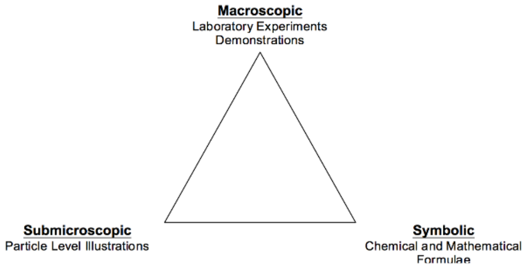


**Figure 1.**Johnstone's Triangle of Levels of Representation [37]

According to Figure 1, the three dimensions are interconnected and contribute to students' ability to understand and comprehend abstract chemistry. This is supported by a statement that chemistry involves processes of material change that can be observed in terms of (e.g., changes in color, odor, bubbles) in macroscopic or laboratory dimensions, but not changes that can be observed with the senses [38]. Modeling is the only way to make changes to structures or processes at the submicroscopic or imaginary molecular level visible to the naked eye. These molecular changes are then abstractly symbolically described in two ways: qualitatively using special notation, language, diagrams, and symbols, and quantitatively using mathematics (equations and graphs).

This perspective demonstrates the dynamic nature of chemistry and is always intriguing to investigate. Students must appreciate how quickly scientific ideas develop to help develop their scientific epistemology. Current technological advances, such as nanotechnology, enhance submicroscopic level images, potentially providing a more adequate visualization aid to teach this level, even though the resulting projection remains a representation.

Students cannot use chemical representations if they do not understand the model's characteristics . The term modeling is often used broadly to refer to the representation of ideas, objects, events, processes, or systems. However, modeling in chemistry refers to a physical or computational representation of a molecule's or particle's composition and structure (submicroscopic level). The structure of a molecule or particle model (submicroscopic) can be represented using physical models, animations, or simulations.

Such modeling abilities are required for success with chemical representations. When students consider a chemical model, for example, a relationship is formed between an analogy and a target that is analogous to a symbolic representation (of various types) with two real targets, namely the submicroscopic level (target 1) and the macroscopic level (target 2). (target 2). The symbolic representation, in this case, is an analogy of the macro and sub-microscopic levels being targeted [26], [32].

Concerning the three chemical representations, various research findings regarding student problems, namely: (1) students' lack of macroscopic experience due to a lack of appropriate practical experience or a lack of clarity about what they should learn through lab work (practicum).) ; (2) the occurrence of submicroscopic misconceptions as a result of confusion about matter particle properties and the inability to visualize entities and processes at the submicroscopic level; (3) a failure to comprehend the complexities of the conventions used to represent the symbolic level; and (4) a lack of ability to switch between the three levels of representation [32].

## CONCLUSSION

The term represents can refer to several things, such as symbolizing, recalling thoughts through images or imagination, and providing a depiction. According to Johnstone, there are three levels of representation: macroscopic (all descriptions of chemical substances, changes, and reactions visible to the senses), submicroscopic (the representation of matter based on its particulate properties), and symbolic (various image and algebraic representations, symbols, and mathematical relationships in chemistry are found at the symbolic level). The three levels of representation, macroscopic, submicroscopic, and symbolic, are interconnected and help students understand and comprehend abstract chemistry. This conclusion recommends that the Johnstone level of representation be developed and integrated into science learning in schools to be able to solve chemistry problems using representation skills and students can accommodate various modes of representation chemical.

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