Jurnal Pembelajaran Kimia *OJS*
Vol. 7, No. 2, December 2022, hal. 58-72 *Universitas Negeri Malang*

ANALYSIS OF THE USE OF ANALOGY OF CHEMICAL EDUCATION STUDENTS ON THE CONCEPT OF CHEMICAL BOND

Fajar Naqsyahbandi[1], Mulyatun, Apriliana Drastisianti, Jajang Muhariyansah

Universitas Islam Negeri Walisongo Semarang

Abstract – The analogy is a valuable pedagogical tool for educators because, by using an analogy, abstract concepts in chemistry can be explained effectively. Therefore, prospective educators need to understand analogies. This qualitative descriptive study aims to analyze and describe the analogy used by chemistry education students on the concept of chemical bonds. The test instrument used the form of 10 open-ended questions been validated by an expert. The results showed three types of analogies: simple analogies, enriched analogies, and extended analogies. This analogy is still single, with the lowest average percentage in the extended analogy type of 5%, while the enriched analogy type is at a percentage of 24%. The analogy type mostly used by students is a simple analogy type with an average percentage of 31 %, and as much as 40% of students do not analogize the existing concept of chemical bonds.

Keywords: *Analogy, Chemical Bonding, Chemistry Education Students*

INTRODUCTION

Chemistry learning is a natural science learning process that studies matter and its changes. Chemical changes involve substances in the form of elements and compounds. Chemistry is considered difficult to understand (Chandrasegaran et al., 2007; Suja, 2014). One of the reasons is that there is a study of representation at the sub-microscopic level which causes chemistry to have abstract concepts (Indrayani, 2013; Nufida, 2013; Suja, 2014) and to understand chemistry requires a high level of reasoning. The study of sub-microscopic level representation is part of the use of three levels of representation (Multiple Level of Representation) chemical. Multiple Level of Representation (MLR) in chemistry learning is used to describe and explain chemical phenomena (Chandrasegaran et al., 2007; Indrayani, 2013).

The three levels of chemical representation are: (1) macroscopic level representation which describes a real phenomenon that can be seen in everyday life (such as color changes, gas formation, odor formation, and precipitate formation), (2) sub microscopic level representation which includes phenomena at the particle level such as atoms, molecules, ions, (3) symbol level representation involving the use of chemical symbols, formulas and calculations (Chandrasegaran et al., 2007). Problems in understanding abstract chemistry are usually solved by scientists and educators using analogies (Didiş, 2015; Nufida, 2013; Wilberls & Duit, 2006). This is in line with the opinion expressed by Harrison dan Coll (2013) that is, without the use of analogies in chemistry learning, abstract concepts in chemistry cannot be explained effectively.

[1]Corresponding author: Jl. Walisongo No.3-5, Tambakaji, Kec. Ngaliyan, Kota Semarang, Jawa Tengah 50185, Indonesia. Email: *fajar.naqsyahbandi@gmail.com*

ISSN 2528-6536 (print)/ISSN 2579-5945 (online) @2022 J-PEK

Analogies are higher-order thinking tools that help students understand natural phenomena effectively (Harrison & Coll, 2013). Analogies can help students and educators learn and explain new information in a simpler way, by comparing it with the information they already know. (Didiş, 2015; Slavin, 2006). Prastowo (2011) in his research states that analogies are indispensable in learning, especially in material that is beyond the reach of the human senses such as learning chemistry. Analogies can also be used in developing science learning creations and innovations, which can train thinking skills and develop critical, logical and analytical thinking attitudes in students.

Analogy can be a double-edged sword (Harrison & Coll, 2013). Research result (Praswidiarini & Suyono, 2015) shows that the application of an analogy strategy, which is strengthened by practicum, is an effective preventive measure in suppressing the potential for student misconceptions. Study Yusuf et al. (2017) also shows learning outcomes using effective analogies to prevent misconceptions, seen from a significant decrease of 14.68% in the experimental class that was given treatment. However, Suja (2014) argues that learning by using analogy can also lead to misconceptions, if the analog concept used is not in accordance with the target concept or is not mapped properly. For example, when using the analogous concept of a seesaw and a U-tube to explain the concept of a chemical equilibrium target, it is irrelevant. The seesaw in this concept is a form of static balance, while chemical equilibrium is a dynamic thing. Therefore, the analogy using this model cannot be used. Good use of analogies cannot be separated from the ability of educators to explain the concept of analog and target, the familiarity of students with analogues, and the ability of both to map between the same features (Harrison & De Jong, 2005).

The ability of an educator to explain a concept is part of the competence that must be met by an educator to become a professional educator. Therefore, the government has required an educator to fulfill the four teacher competencies in accordance with Law no. 14 of 2005, namely pedagogic competence, personality competence, social competence, and professional competence. UIN Walisongo Semarang has specifically educated, facilitated and prepared prospective chemistry educator students to become professional and competent chemistry teachers through the Chemistry Education Study Program at the Faculty of Science and Technology. Chemistry Education students are forged through courses that are arranged systematically and comprehensively, both through compulsory subjects and elective courses, for example basic chemistry 1 and basic chemistry 2 courses which discuss basic concepts or the core of chemistry.

Basic chemistry course 1 is a prerequisite course for basic chemistry course 2 and these two courses are prerequisite courses for further learning chemistry courses. One of the important materials in learning basic chemistry 1 is chemical bonds. Chemical bonding requires a thorough understanding of concepts to master advanced materials in chemistry such as organic chemistry, acids and bases, chemical energy and thermodynamics(Nahum et al., 2007). Based on the results of a perception questionnaire from 61 students of the Chemical Education Study Program, UIN Walisongo Semarang, they still showed difficulties in chemical bonding material, such as in the formal charge sub material as much as 33%, VSEVR theory as much as 39%, Valence bond theory and Orbital Hybridization as much as 48%, Orbital Theory Molecular as much as 46% and the polarity of the compound as much as 43%. However, in other chemistry subjects, no more than 28% of students stated difficulties. This is in line with research Tan and Treagust (1999) which states that many students have difficulty understanding the concept of chemical bonds because chemical bonds are an abstract topic. Even though the concept of chemical bonds is very important for students to master. Siska et al. (2013) stated that it is very important for students (students) to master the concept of prerequisite material before receiving the next learning material, for example the concept of chemical bonds. This is in line with the research results Nakhleh (1992) related to the number of students at all levels who are not able to master the knowledge of chemistry because the majority of them from the beginning of learning did not build an understanding of concepts. Therefore, chemistry education students need good mastery of chemical concept knowledge, in order to fulfill content knowledge as prospective educators. In addition, chemistry education students as prospective educators must also be able to transform the content of the material into a form that is easily understood by students (Shulman, 1986) or in other words mastering pedagogical knowledge (pedagogic knowledge).

Based on the description that has been explained that, besides being able to help explain abstract information in a simpler way, it also has the potential to cause misconceptions. One form of prevention for prospective educators so that they are not mistaken in analogizing a target concept and do not cause misconceptions in the use of the concept, it is necessary to research on the use of analogies for prospective educators (chemistry education students), especially on prerequisite materials such as important chemical bonds. for further study. Harrison and De Jong (2005) stated that there are still few studies that conduct research on analogies in chemistry education. Most studies on analogy discuss about learning physics and biology and focus on using educator analogies in classroom practice, so researchers are encouraged to carry out this research.

METHOD

This research is a qualitative descriptive study examining: (1) what are the analogies used by chemistry education students on the concept of chemical bonds? (2) how to describe the analogy used by chemistry education students on the concept of chemical bonds. Qualitative descriptive research is research that explains and describes scientific phenomena and engineering, which observes the nature, quality, and associations between activities. Without any treatment, manipulation, or change in variables, so that it describes the actual condition. The study was conducted using a purposive sampling technique on the fourth semester students of the Chemistry Education study program at UIN Walisongo Semarang at the Chemistry Education Study Program, UIN Walisongo Semarang (Campus II), Jl. Prof. Dr. Hamka, KM 2 Ngaliyan Semarang.

Collecting data in this study used a questionnaire as the first step for researchers to determine the study of research material regarding basic chemistry 1 which students of UIN Walisongo chemistry education consider difficult/not yet understood. Furthermore, a non-test instrument was used in the form of an open-ended question which had been validated by expert lecturers as many as 10 questions, with question indicators representing important topics in the concept of chemical bonds. Giving questions is done after all chemical bonding material is given to students. Finally, the use of interviews to strengthen the results of the data that has been obtained by researchers and to obtain more in-depth information regarding the analogy used by chemical education students at UIN Walisongo Semarang.

The analogy data obtained were checked and compared with data to obtain credible data results using triangulation techniques. Then the data in this study were analyzed using the Miles and Huberman model (Sugiyono, 2012). The data obtained from chemical education students of UIN Walisongo Semarang class of 2018 carried out the process of collecting, selecting, focusing and simplifying the data that had been obtained by the researchers. Categorization and grouping is carried out on data that is important, meaningful, and relevant to the research objectives, so that the results of the reduced data can provide clearer data and make it easier to collect data. From the results of data reduction, then presented in the form of tables and systematic descriptions so that they are easy to read and understand. At this stage, analysis and classification of analogies are also carried out into 3 types of analogies, namely simple analogies, enriched analogies and expanded analogies. Classification is based on the answers to the questions given, enters into the simple analogy type if it does not include the reasons underlying the comparison in the analogy, enters the enriched analogy type if it mentions the reasons or conditions for the equation of the analogy and enters the enriched analogy type if it can mention some attributes and limitations of the analogy. The last stage, the initial conclusions that have been obtained are still temporary and can be credible conclusions if they are supported by valid and consistent evidence.

RESULTS AND DISCUSSION

Analogy Used by Chemistry Education Students on the Concept of Chemical Bonds

This study aims to analyze the analogy used by chemistry education students on the concept of chemical bonds. This research data collection used a non-test instrument in the form of an open questionnaire which was conducted from June 1 to June 19, 2020. This data collection was attended by 50 students of 2018 class of chemistry education who had completed chemical bonding material in the basic chemistry course 1.

The question description on the test instrument is in the form of an open-ended question as many as 10 items which have been validated by 2 expert lecturers. Each item represents an important subject in the concept of chemical bonds which is divided into 5 indicators. These indicators include categorizing the types of chemical bonds, detailing the concept of bond energy, interpreting the VSEPR concept, studying the concepts of valence bond theory and the concept of molecular orbital theory. Students are asked to answer the description questions using an analogy that is easily understood by students, considering that the student is a prospective educator.

Student answers from the student's analogy use test were analyzed and classified into 3 types of analogies, namely simple analogies, enriched analogies and expanded analogies (Harrison & Treagust, 2006). The type of simple analogy is a type of analogy that does not include the reasons underlying the comparison in the analogy, the type of enriched analogy is a type of analogy that states the reasons or conditions for the equation of the analogy while the type of enriched analogy is a type of analogy that can mention some of the attributes and limitations that are shared in the answered analogy. by student.

Based on the results of the students' use of analogies tested, the average percentage of the types of analogies used by students is shown in Figure 4.1. It is known that the average percentage of the type of analogy used by students is the lowest, which is 5%, which is found in the type of expanded analogy. The type of extended analogy occupies the lowest position on all question indicators. While the highest average percentage is found in the type of simple analogy as much as 31%. The type of simple analogy dominates in all indicators, with the highest percentage found in the indicator of the bond energy concept (38%). The type of enriched analogy has an average percentage of 24%, with the highest percentage found in the VSEPR concept question indicator (32%). The percentage of types of analogies used by students in each question indicator can be seen in Figure 4.2.

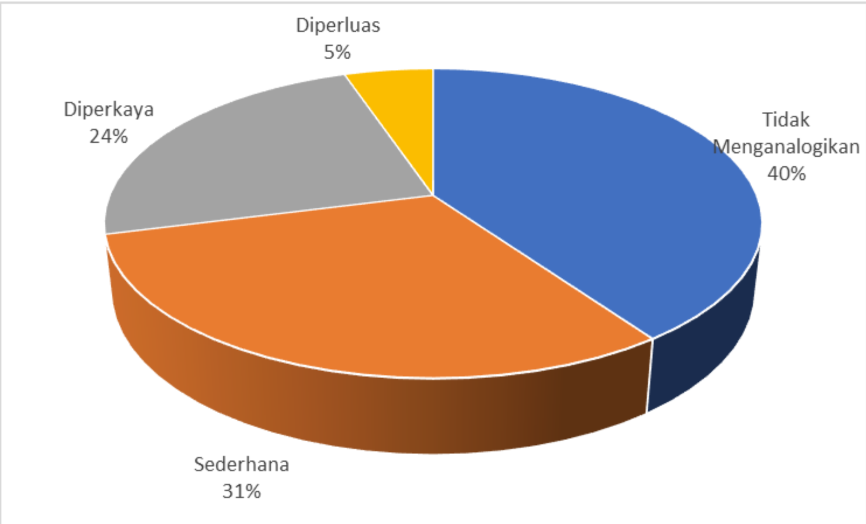

Figure 1 Graph of the average percentage of types of analogies used by students in the concept of chemical bonds

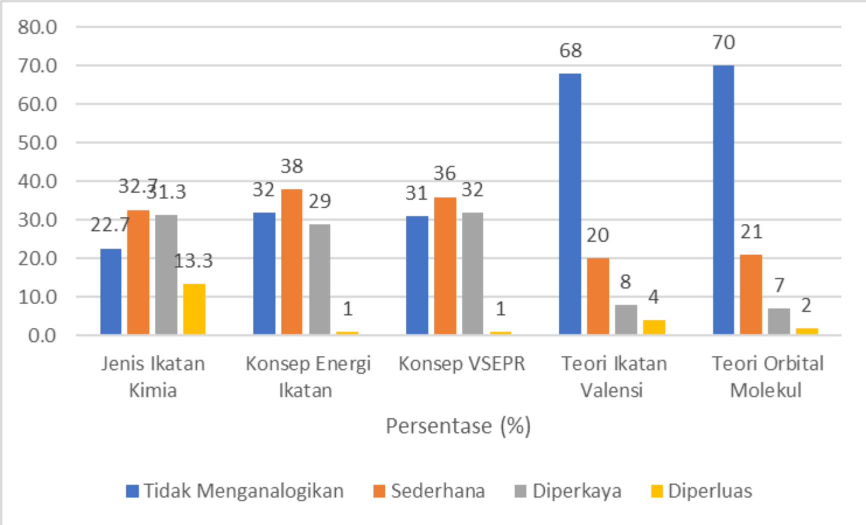

Figure 2 The graph of the percentage distribution of the type of analogy for each question indicator

Based on Figures 1 and 2, it can be seen that students still find it difficult to produce an analogy. This is evidenced by the highest average percentage for the category of students who do not make an analogy of 40%. In line with the dominance of 2 question indicators, namely the valence bond theory indicator at 68% and the molecular orbital theory at 70%. Research conducted Harrison & Treagust (2006) also states that it is rare for students to produce appropriate analogies and do not lead to alternative conceptions.

In detail, the percentage of types of analogies used by students for each question can be seen in Figure 3.

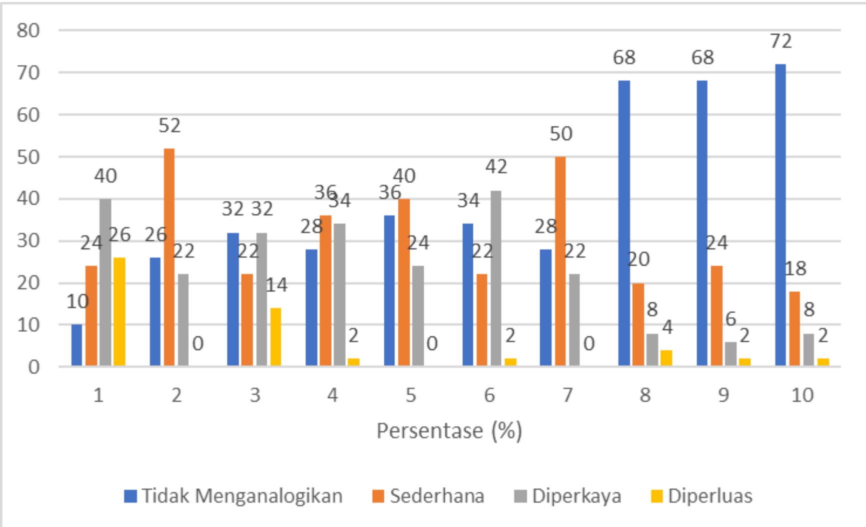

Figure 3 Percentage distribution graph of the type of analogy for each question number

As shown in Figure 3, for the distribution of the percentage of the type of analogy in each question number. the type of simple analogy got the highest percentage in question number 2 by 52%. For the analogy model enriched, the highest average percentage is found in question number 4 at 42%. While the highest average percentage for the type of analogy enriched by 26% is found in question number 1. There are 3 question numbers with an average percentage of more than 65% for the category of students who do not make analogies, namely in question numbers 8, 9 and 10.

Description of the Analogy Used by Chemistry Education Students on the Concept of Chemical Bonds

Based on the description of the data presented in Figures 1 and 2, it is known that the analogy used by chemistry education students on the concept of chemical bonds in general is a simple type of analogy. This is indicated by the average percentage value of the type of simple analogy used by students of 31%. Many types of simple analogies were found in the research because students only mentioned comparisons of analogous concepts and target concepts without mentioning the reasons underlying the comparisons. As for the analog concept of the simple analogy type, some students included reasons for the comparison between the analog concept and the target, which was 24% of the type of analogy being enriched. Research conducted Suja (2014) also found many uses of analogies that are still singular and have not been accompanied by mapping the similarity of analog features to the target concept.

The details of the type of analogy used by students will be discussed in this study including 5 indicators of chemical bonding material, including the type of chemical bond, the concept of bond energy, the VSEPR concept, valence bond theory and molecular orbital theory. The following is a detailed discussion for each indicator.

1. Various analogies used by students on types of chemical bonds

In obtaining the analogy used by students on the type of chemical bond, students are presented in writing 3 types of chemical bonds to be analogous, namely ionic bonds, covalent bonds and metallic bonds.

The following are various analogies used by students to explain the types of ionic bonds shown in Table 1.

Table 1 analogy used by students in ionic bonds

Topics	Analogy Name	Analog	Target	Attribute
Types of Chemical Bonds	Couple Analogy[α,3]	Boy and girl couple	ionic bond	• Men and women vs. cations and anions • Care and affection vs. transferred electrons • Relationship harmony vs. bond stability
Types of Chemical Bonds	Blood Donation Analogy[α,2]	Blood donation system	ionic bond	• Blood donors and acceptors vs. metal atoms and non-metal atoms • Blood bags vs. electron
Types of Chemical Bonds	Generous analogy[α,2]	Share property	ionic bond	• A philanthropist divides wealth vs. cations transfer electrons to anions • Social inequality is decreasing vs. potential energy decreases
Types of Chemical Bonds	Alms analogy[α,1]	give charity	ionic bond	• People giving charity to the less fortunate vs. metal atoms transfer electrons to nonmetal atoms

[α] analogy named by researcher. [1] simple analogy. [2] analogy enriched. [3] expanded analogy.

Ionic bonds are bonds that occur when there is a transfer of electrons between metal atoms and non-metal atoms to form positive ions or cations and negative ions or anions. The two ions attract each other, lowering their potential energy and forming a bond (Tro, 2010). The formation of ionic bonds is analogous to chemistry education students with several analogies as shown in Table 1.

Pair analogy is used to analogize male and female pairs such as ionic bonds. a man who gives attention and affection to women to create harmony in a relationship is analogous to a cation that transfers electrons to an anion to achieve a stable configuration and an ionic bond is formed.

The blood donor analogy is analogous to a person who donates blood to an acceptor who receives the blood as a metal atom that transfers electrons to a non-metal atom. In this case, the transferred blood bag is analogous to an electron involved in the formation of an ionic bond.

Ionic bonds by students are also analogous to being a philanthropist who distributes his wealth so that it can reduce social inequality among the community. Wealth and goods shared by benefactors are analogous to electrons in the formation of ionic bonds and reducing social inequality is analogous to the formation of bonds marked by a decrease in potential energy.

The alms analogy analogizes the ionic bond as a person who gives alms to people who are less fortunate. people who give charity analogize metal atoms that transfer electrons, while people who are less able to analogize non-metal atoms that receive electrons so that ionic bonds occur.

The following are various analogies used by students to explain the types of covalent bonds shown in Table 2.

Table 2 the analogy that students use on covalent bonds

Topics	**Analogy Name**	**Analog**	**Target**	**Attribute**
Types of Chemical Bonds	Joint analogy[α,2]	money joint	covalent bond	• Two joint ventures vs. two atoms involved in a covalent bond • Money is used for common purposes vs. shared electron pairs
Types of Chemical Bonds	Salary analogy[α,2]	Husband and wife salary	covalent bond	• Husband and wife combine salary vs. two atoms involved in a covalent bond • Shared salaries vs. shared electron pairs
Types of Chemical Bonds	Textbook analogy[α,1]	Textbook Usage	covalent bond	• One Textbook shared vs. shared electron pairs
Types of Chemical Bonds	Closet analogy[α,1]	Buying a wardrobe	covalent bond	• Fees for buying a shared wardrobe vs. shared electron pairs

[α] analogy named by researcher. [1] simple analogy. [2] analogy enriched. [3] expanded analogy.

A covalent bond is formed when a nonmetal atom bonds to another nonmetal atom with a pair of electrons shared between the two atoms to bond (Chang, 2010). There are 4 analogies used by students for covalent bonds: first, the analogy of a joint venture which analogizes two people sharing money for the fulfillment of common needs as two atoms involved in the formation of a covalent bond and money used in the joint activity, analogous to a pair of electrons shared between two atoms in a covalent bond.

Second, the salary analogy is the analogy of a husband and wife combining their salaries and then the salaries are used together for daily needs. In this case, the husband and wife pair are analogous to the two atoms involved in the formation of a covalent bond and the pay as a pair of electrons that are shared in the bond.

Third, the textbook analogy is the analogy of two students using a textbook together as two atoms in a covalent bond that use a shared pair of electrons to form a bond. Fourth, the analogy of a cupboard which analogizes two children who pay fees to buy 1 cupboard and then the cupboard is used together as two non-metal atoms that emit electrons to form a bonding electron pair together.

The following are various analogies used by students to explain the types of metallic bonds shown in Table 3.

Table 3 analogy students use on metallic bonds

Topics	Analogy Name	Analog	Target	Attribute
Types of Chemical Bonds	Ball analogy[α,3]	Ball in the basin	metal bond	• Ball in a basin of water vs. positive metal ions surround a sea of electrons • Fully filled water vs. delocalized electrons • Water pushed by the ball vs. electrons overlap and move freely between metal ions
Types of Chemical Bonds	The analogy of a cilok seller[α,2]	Sellers and buyers of cilok	metal bond	• Small seller surrounded by buyers vs. positive metal ion surrounded by electrons (sea of electrons)
Types of Chemical Bonds	Ball and marble analogy[α,1]	Balls and marbles	metal bond	• Balls and marbles in one bowl vs. positive metal ions surround a sea of electrons
Types of Chemical Bonds	Fruit ice analogy[α,1]	Fruit ice	metal bond	• Fruits and water vs. positive metal ion surrounded by a sea of electrons

[α] analogy named by researcher. [1] simple analogy. [2] analogy enriched. [3] expanded analogy.

Metallic bonds occur in metal atoms that have low ionization energies so they tend to easily lose electrons, causing delocalized valence electrons in metal atoms known as "electron seas". There is an overlap between electrons in a sea of electrons and electrons move freely between positively charged metal ions, resulting in an electrostatic attraction and a metal bond is formed (Tro, 2010).

It was found that there were 4 analogies used by the 2018 UIN Walisongo chemistry education students to understand metallic bonds. First, students use the analogy of a ball, which means that a ball is placed in a basin filled with water to the brim as positive metal ions surrounded by a sea of electrons. Water in a fully filled basin is analogous to delocalized electrons forming a sea of electrons and when water is pushed by a ball in the basin, water is analogous to electrons overlapping each other and moving freely between metal ions.

Second, metallic bonds are analogous to cilok sellers surrounded by buyers as positive metal ions surrounded by electrons that overlap and move freely around positive metal ions. In this situation, the seller of cilok is analogous to a positive metal ion. Third, the 2018 UIN Walisongo chemistry education student analogized the state of a positive metal ion surrounded by a sea of electrons as a ball surrounded by marbles in a basin. Balls are analogous to positive metal ions while marbles are analogous to a sea of electrons in a metallic bond.

The four chemistry education students used the analogy of fruit ice to describe metallic bonds. Fruits and water in fruit ice are analogous to positive metal ions surrounded by a sea of electrons in a metallic bond.

2. Various analogies used by students on the concept of bond energy

In obtaining the analogy used by students in the concept of bond energy, students are presented in writing with 2 pieces of material to be analogous, namely bond energy material and Lewis theory.

The following are the various analogies used by students to explain the bond energy material shown in Table 4.

Table 4 the analogy that students use on bond energies

Topics	Analogy Name	Analog	Target	Attribute
Bonding Energy	Spring analogy[α,1]	Spring disconnect	Bond breaking	• Energy to break the spring and. enthalpy change for breaking bonds
Bonding Energy	Fighter analogy[α,3]	Fighter breaks bricks	Bond breaking	• Fighters eat to break bricks vs. enthalpy change required to break bonds • Lots of dinner plates vs. big enthalpy change
Bonding Energy	Cashier analogy[α,2]	Number of transactions	Bond energy	• Paying for items at the cashier vs. bond breaking process • Amount paid vs. big enthalpy change
Bonding Energy	Knife analogy[α,2]	Cutting fruit with a knife	Bond breaking	• Cutting fruit vs. break ties • Knives used vs. required enthalpy change

[α] analogy named by researcher. [1] simple analogy. [2] analogy enriched. [3] expanded analogy.

Bond energy is the enthalpy change required to break certain bonds in one mole of gas molecules (Chang, 2010). This study found 4 analogies used by chemical education students of UIN Walisongo class 2018. First, the analogy of breaking a spring is to analogize the breaking of bonds. the student states that it takes a certain amount of energy to break a spring in analogy to the enthalpy change required to break the bonds of gas molecules.

Second, the fighter's analogy is that a fighter needs to eat to be able to perform the attraction of breaking bricks as the enthalpy change needed to break bonds. The amount of food a fighter needs is analogous to the amount of enthalpy change required to break bonds.

Third, the cashier's analogy is the analogy of paying for groceries at the cashier as a process of breaking ties. The amount of money paid to buy goods at the supermarket is analogous to the amount of enthalpy change required to break bonds. Fourth, the 2018 UIN Walisongo chemistry education student analogized breaking a bond like cutting fruit using a knife. The knife is analogous to the enthalpy change required for bond breaking.

The following types of analogies used by students to explain Lewis' theory are shown in Table 5.

Table 5 analogy used by students in lewis theory

Topics	Analogy Name	Analog	Target	Attribute

Lewis theory	Prophet's Analogy[α,1]	Prophet Muhammad SAW	Octet rule	• The role model of the prophet Muhammad SAW vs. isoelectronic atoms with noble gases to stabilize
Lewis theory	Parent analogy[α,1]	Parental behavior	Octet rule	• Children imitate parental behavior vs. isoelectronic atoms with noble gases to stabilize
Lewis theory	Wheel analogy[α,1]	car wheel	Octet rule	• Stable car with 4 wheels vs. stable atom with 8 electrons (octet)
Lewis theory	Dot analogy [2]	Point	Electron	• Dot (dot) or X vs. electrons involved in the formation of molecules

[α] analogy named by researcher. [1] simple analogy. [2] analogy enriched. [3] expanded analogy.

Lewis theory explains that atoms form bonds to achieve a more stable electron configuration and atoms can achieve maximum stability when they are isoelectronic with noble gases (Chang, 2010). There are 4 analogies that students use to understand Lewis theory. First, atoms that are isoelectrons with noble gases to achieve maximum stability are analogous to humans who made the Prophet Muhammad SAW a role model for Muslims.

Second, the analogy of parents who analogize children imitate the behavior of their parents such as atoms that are isolectrons with noble gases to achieve maximum stability. Third, the octet rule that states atoms except hydrogen tend to form bonds until the atom is surrounded by 8 valence electrons is analogous to a stable car with 4 wheels.

Fourth, the dot analogy which analogizes the valence electrons involved in the formation of the molecule as a dot (dot) or X sign.

3. Various analogies used by students in the VSEPR concept

In obtaining the analogy used by students in the VSEPR concept, students were presented in writing with the VSEPR theory and several geometric shapes of molecules.

The following are various analogies used by students to explain the concept of VSEPR which are shown in Table 6.

Table 6 analogy used by students in VSEPR teori theory

Topics	Analogy Name	Analog	Target	Attribute
VSEPR theory	balloon analogy [3]	balloons	Covalent Molecule	• Air-filled balloons vs. electron pair • Four balloons tied around the neck vs. four sigma bonds around one carbon atom • Air pressure pressing each balloon vs. bonds repel each other • One popping balloon vs. double bond • Two popping balloons vs. triple bond
VSEPR theory	Toothpick analogy[α,2]	Toothpick and plasticine	Molecular geometry	• Toothpick vs. covalent bond • Plasticine vs. electron pair
VSEPR theory	Analogy of building space[α,1]	geometry	Molecular geometry	• Barbells vs. linear • Equilateral triangle vs. Trigonal planar • Pyramid of triangular base vs. Tetrahedral

				• Two triangular base pyramids joined vs, Trigonal bipyramid • Two rectangular base pyramids joined vs. octahedral

[α] analogy named by researcher. [1] simple analogy. [2] analogy enriched. [3] expanded analogy.

VSEPR theory explains the geometric arrangement of electron pairs around a central atom as a result of repulsion between electron pairs (Chang, 2010). There are 3 types of VSEPR theoretical analogies used by students (Table 6). first, the balloon analogy, which analogizes covalent molecules to balloons. An air-filled balloon represents a pair of electrons and four balloons tied at the neck analogous to four sigma bonds surrounding a single carbon atom or a tetrahedral molecular geometry. The air pressure pressing down on each balloon visualizes the bonds repelling each other. When one balloon bursts, the remaining three balloons form a trigonal planar or double bond. When the second balloon pops, the two remaining balloons form a linear or triple bond.

Second, the shape of the molecular geometry is analogous to that of a toothpick and molded plasticine. Toothpicks are analogous to covalent bonds while plasticine is analogous to electron pairs. Third, the analogy of spatial shapes which analogizes molecular geometric shapes such as spatial shapes that are often encountered in everyday life. Such as a barbell for a linear shape, an equilateral triangle for a planar trigonal shape, a triangular base pyramid for a tetrahedral shape, two triangular base pyramids joined for a trigonal bipyramidal shape, two rectangular base pyramids joined for an octahedral shape.

4. Various analogies used by students in valence bond theory

In obtaining the analogy used by students in valence bond theory, students are presented in writing on valence bond theory.

The following types of analogies used by students to explain the valence bond theory are shown in Table 7.

Table 7 analogy used by students in valence bond theory

Topics	Analogy Name	Analog	Target	Attribute
Valence Bond Theory	Solution analogy[α,2]	Colored solution	Hybridization	• Two different colored solutions in different glasses vs. two orbitals that will undergo electron promotion • Mixed solutions vs. atomic orbitals overlap • New colored solution is formed vs. hybrid orbitals
Valence Bond Theory	shake hands analogy[α,1]	Two people shaking hands	valence bond theory	• Hands of two people shaking hands vs. two atomic orbitals overlap

[α] analogy named by researcher. [1] simple analogy. [2] analogy enriched. [3] expanded analogy.

Valence bond theory assumes that a bond is formed between two atoms when two electrons with paired spins are shared by two overlapping molecular orbitals, one orbital from each of the atoms joining to form a bond. (Jespersen et al., 2012).

There are two kinds of analogies used by students for valence bond theory. First, the solution analogy which analogizes the concept of hybridization. Two different colored solutions in each different glass are mixed until a new color is formed. just like two orbitals that will experience electron promotion, overlap each other to form a hybrid orbital.

The second analogy is the shaking hands analogy, which analogizes the hands of two people shaking hands overlapping each other like two overlapping atomic orbitals.

5. Various analogies used by students in molecular orbital theory

In obtaining the analogy used by students in molecular orbital theory, students are presented in writing with 2 materials, namely, molecular orbital theory and bond order.

The following are various analogies used by students to explain the molecular orbital theory shown in Table 8.

Table 8 analogy used by students in molecular orbital theory

Topics	Analogy Name	Analog	Target	Attribute
Molecular Orbital Theory	Mixed analogy[α,3]	Colored mix	Molecular Orbitals	• Mixing two different colored solutions in a beaker and. interaction of atomic orbitals of bonded atoms
Molecular Orbital Theory	Search analogy[α,2]	Couple search	Magnetic properties	• Looking for a partner and paramagnetic properties • Already paired and. diamagnetic properties
Molecular Orbital Theory	combined class analogy[α,1]	Combined class	Atomic orbital interactions	• Combined interactions between classes A, B, and C vs. interaction of atomic orbitals of bonded atoms
Molecular Orbital Theory	Ferris wheel analogy[α,1]	Ferris wheel	Molecular Orbitals	• Position of the carriage below and above vs. bonding and antibonding molecular orbitals

[α] analogy named by researcher. [1] simple analogy. [2] analogy enriched. [3] expanded analogy.

Molecular orbital theory is a theory of covalent bonds resulting from the interaction of atomic orbitals of atoms that are bonded and associated with the whole molecule. Students make an analogy of a mixture of colors. mixing two solutions of different colors from inside different glasses such as the interaction of atomic orbitals of bonded atoms.

Another analogy for the interaction of atomic orbitals of bonded atoms is the compound class analogy. There was a combined interaction between students from class A, B, and C during the learning process.

Paramagnetic properties that can attract metals are analogous to people looking for a partner until someone is attracted to them. Meanwhile, diamagnetic properties are analogous to people who are already paired so that they reject the other.

The Ferris wheel analogy compares the position of the bonding molecular orbitals which have lower energy and greater stability than the antibonding molecular orbitals with the carriage positions of the Ferris wheel. The lower carriage is the bonding molecular orbital and the upper carriage is the antibonding molecular orbital.

The following are the various analogies used by students to explain the bond order shown in Table 9.

Table 9 the analogy that students use on the bond order

Topics	Analogy Name	Analog	Target	Attribute

Molecular Orbital Theory	wall analogy[α,1]	Wall layer	Bond order	• Number of layers of walls vs. number of bond orders
Molecular Orbital Theory	Friends analogy[α,2]	Friends and foes	Bonding and antibonding molecular orbitals	• The number of friends and enemies in the class and. the number of bonding and antibonding molecular orbitals • More comfortable classes vs. more stable molecule
Molecular Orbital Theory	Weight analogy[α,3]	Balloon tied with ballast	Molecular Orbitals	• Weights and balloons vs. bonding molecular orbitals and antibonding orbitals • Balloons don't fly when more ballast vs. a molecule is stable when there are more bonding molecular orbitals

[α] analogy named by researcher. [1] simple analogy. [2] analogy enriched. [3] expanded analogy.

Bond order is used to express the strength of a bond, a molecule will be more stable if the number of electrons in the bonding molecular orbital is more than the number of electrons in the antibonding molecular orbital (Chang, 2010).

There are 3 analogies that students use on the bond order. First, the strength of a bond expressed by the bond order is analogous to that of a wall layer. The more layers of the wall, the stronger the wall. Second, the number of friends and enemies in a class is analogous to the number of bonding molecular orbitals and antibonding molecular orbitals. Classes are more comfortable when there are more friends in it as well as molecules, which are more stable when the number of bonding molecular orbitals is greater than the number of antibonding molecular orbitals.

Third, the analogy of the ballast which is analogous to the bonding molecular orbitals. When a balloon is tied to a ballast, the balloon cannot fly or in other words it is stable. The balloon is analogous to an antibonding molecular orbital and the position of the balloon and the ballast does not fly analogous to a stable molecule when the number of bonding molecular orbitals is greater than the number of antibonding molecules.

Based on the results of the presentation of the type of analogy used by students on each indicator, it is feasible to use. By using these analogies, researchers have carried out mapping of feature similarities between the analog concept and the target concept, but it has not been accompanied by a feature boundary between the two concepts that has the potential to cause misinterpretation and misconceptions for students (Suja, 2014). This is because students still have difficulty in analogizing a target concept being studied.

Overall, the high percentage of students who do not make an analogy to the concept of chemical bonds is caused by several factors. First, students have not built an analogy based on proportional knowledge like an educator. An educator has the perspective that the analogous relationship between the analog concept and the target concept rests on the structure of the subject matter that relies on knowledge based on propositions (Wilberls & Duit, 2006). Students are still constructing an analogy based on mental images and interpreting analogous concepts and targets in a different way than an educator.

Second, an analogy must be familiar with students to increase motivation and interest in learning. One factor that is often overlooked when using analogies is the social environment (Harrison, 2006). Students still lack in terms of social knowledge and teaching experience, while this is the best and most effective source of analogy teaching.

CONCLUSION

This research shows that although the concept of chemical bonds is abstract and difficult to understand, analogies are still built and used by students in understanding chemical topics. There are 3 types of analogies used by the fourth semester Chemistry Education students who are the research subjects, namely simple analogies, enriched analogies and expanded analogies, with the number of identified analogies as many as 32 analogies. 12 analogies to the types of chemical bonds, 8 analogies to the concept of bond energy, 3 analogies to the VSEPR concept, 2 analogies to valence bond theory, and 7 analogies to molecular orbital theory.

The results of the analysis show that the type of analogy used by students in the concept of chemical bonds is still single. The average percentage for the type of analogy is expanded at least 5%, while for the type of analogy is enriched it is at a percentage of 24% and the type of analogy used by students is mostly in the type of simple analogy with an average percentage of 31% and as much as 40% does not make an analogy. the concept of a chemical bond. This condition is because students' knowledge has not been built proportionally and still lacks pedagogical experience. For this reason, it needs to be improved in order to clarify the understanding of complex chemical concepts.

REFERENCES

Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2007). The development of a two-tier multiple-choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. *Chemistry Education Research and Practice*, *8*(3), 293–307. https://doi.org/10.1039/B7RP90006F

Chang, R. (2010). *Chemistry* (10th ed.). The McGraw-Hill Companies, Inc.

Didiş, N. (2015). The analysis of analogy use in the teaching of introductory quantum theory. *Chemistry Education Research and Practice*, *16*(2), 355–376. https://doi.org/10.1039/c5rp00011d

Harrison, A., & De Jong, O. (2005). Using multiple analogies: Case study of a chemistry teacher's preparations, presentations and reflections. *Research and the Quality of Science Education*, 353–364. https://doi.org/10.1007/1-4020-3673-6_28

Harrison, A. G. (2006). The Affective Dimension of Analogy. In *Metaphor and Analogy in Science Education* (pp. 51–64). Springer.

Harrison, A. G., & Coll, R. K. (2013). *Analogi dalam Kelas Sains*. PT Indeks.

Harrison, A. G., & Treagust, D. F. (2006). Teaching and learning with analogies. In *Metaphor and Analogy in Science Education* (pp. 11–24). Springer.

Indrayani, P. (2013). Analisis Pemahaman Makroskopik, Mikroskopik, dan Simbolik Titrasi Asam-Basa Siswa Kelas XI IPA SMA serta Upaya Perbaikannya dengan Pendekatan Mikroskopik. *Jurnal Pendidikan Sains*, *1*(2), 109–120.

Jespersen, N. D., Brady, J. E., & Hyslop, A. (2012). *Chemistry the Molecular Nature of Matter* (6th ed.). John Wiley and Sons, Inc.

Nahum, T. L., Naaman, R. M., Hofstein, A., & Krajcik, J. (2007). Developing a New Teaching Approach for the Chemical Bonding Concept Aligned With Current Scientific and Pedagogical Knowledge. *Science Education*, *91*(4), 579–603. https://doi.org/10.1002/sce

Nakhleh, M. B. (1992). Why some students don't learn chemistry: Chemical misconceptions. *Journal of Chemical Education*, *69*(3), 191–196. https://doi.org/10.1021/ed069p191

Nufida, B. A. (2013). Model Jembatan Analogi dalam Pembelajaran Kimia untuk Membantu Pemahaman Aspek Mikroskopik Siswa. *Jurnal Kependidikan*, *12*(2), 115–120.

Prastowo, T. (2011). Strategi Pengajaran Sains dengan Analogi Suatu Metode Alternatif Pengajaran Sains Sekolah. *Jurnal Penelitian Fisika Dan Aplikasinya (JPFA)*, *1*(1), 8. https://doi.org/10.26740/jpfa.v1n1.p8-13

Praswidiarini, D., & Suyono. (2015). Penerapan Strategi Analogi yang Diperkuat dengan Praktikum untuk Meprevensi Miskonsepsi Siswa pada Konsep Asam dan Basa. *Unesa Journal of Chemical Education*, *4*(3), 532–540.

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher*, *15*(2), 4–14.

Siska, A., Amran, E. Y., & Herdini. (2013). Pemberian Materi Prasyarat untuk Meningkatkan Prestasi Belajar Siswa pada Pokok Bahasan Larutan Penyangga di Kelas XI SMA Negeri 1 Pekanbaru. *Program Studi Pendidikan Kimia FKIP Universitas Riau*.

Slavin, R. E. (2006). *Educational Psychology Theory and Practice* (8th ed.). Pearson Education, Inc.

Sugiyono. (2012). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D*. Penerbit Alfabeta.

Suja, I. W. (2014). Penggunaan Analogi dalam Pembelajaran Kimia. *Jurnal Pendidikan Indonesia*, *3*(2), 397–410.

Tan, K.-C. D., & Treagust, D. F. (1999). Evaluating Students' Understanding of Chemical Bonding. *School Science Review*, *81*(294), 75–84.

Tro, N. J. (2010). *Principles of Chemistry a Molecular Approach*. Pearson Education, Inc.

Wilberls, J., & Duit, R. (2006). Post-Festum and Heuristic Analogies. In *Metaphor and Analogy in Science Education* (pp. 37–49). Springer.

Yusuf, S. A., Lukum, A., & Tangio, J. S. (2017). Penggunaan analogi dalam pembelajaran kesetimbangan kimia untuk mencegah miskonsepsi mahasiswa kimia Universitas Negeri Gorontalo semester II tahun akademik 2014 / 2015. *Jurnal Entropi*, *12*(1), 109–117.