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# The Analysis of Analogy use in Chemistry Teaching

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**Abstract.** This study identifies students' knowledge about analogies and to explore the potential analogies in chemistry learning. Some issues related to the use of analogies in teaching and learning are discussed. In this study, data were collected from recordings, and interviews. In the interviews, student answered question about chemistry concepts and analogies generally. In addition, the interview revealed that students liked the use of analogies in their classes and believed that they had a positive effect on their understanding of new concepts. According to them, a good analogy is an object or event that is in the natural surroundings, because it will be easier to remember. We present suggestions for improving classroom analogy use

**Keywords:** Analogy; Chemical equilibrium; Teaching; Chemistry.

## 1. Introduction

Chemistry one of the subjects have difficulties in learning. The concepts in chemistry are abstract and students need appropriate instructional to images of the things which cannot be seen. For example, Akani reported that there are several topics of material that students find difficult, including acid-base titration, analysis of qualitative chemical reactions, rate of reaction and influence of energy, composition of non-metals and metals, chemical applications, nuclear chemistry and astronomical chemistry [1]. Ozmen (2008) discussed seventeen alternative conceptions were identified through analysis of the Test Identify Students' Alternative Conceptions (TISAC), these conceptions were grouped under the heading of the applications of Le Chatelier's principle, reliability of the equilibrium constant, heterogeneous equilibrium, an effect of catalyst [2].

In general, in chemistry study there are three levels that must be mastered, namely the level of macroscopic, microscopic and symbolic [3]. At the microscopic and symbolic level is an abstract level because it is not visible to the see [4]. Macroscopic representation is a chemical representation obtained through real observation of a phenomenon that can be seen and perceived by the five senses or in the form of daily experience. Microscopic representation is a chemical representation that explains the structure and process at the level of particles (atomic / molecular) of the macroscopic phenomena observed. Symbolic representations are qualitative and quantitative chemical representations such as chemical formulas, diagrams, picture, reaction equations, stoichiometry and mathematical calculations [5]. All of the concepts must be integrated each other so that learning objectives can be achieved. One of the useful for teaching abstract concepts is analogy. Analogy is comparison of the similarities of two concepts. The familiar concepts was called the analog and the unfamiliar was called the target [6]. Analogy is comparison of the similarities of two concepts. The familiar concepts is called the analog and the unfamiliar one the target [6]. Etymologically, analogies



mean parallel readings. When applied to the domain of science learning, this definition refers to a parallel way to the similarity relationship between certain scientific concepts that want to be conveyed with something real, simple, and already in the mindset of students [7]

Naseriazar, *et al.* said that the problem of difficulties in studying chemical equilibrium can be above by applying analogy-based learning. From the results of his research, it was revealed that students in the experimental group who applied the analogy showed far greater achievement than students in the control group. Based on the results of these studies indicated that the problem of difficulties and misconceptions in learning the concept of chemistry can be overcome by applying learning based on analogies [8]. According to Suparson and Promarak that the application of the 5E model with an analogy approach is an effective way to increase students' conceptual understanding of chemical reactions [9]. Orgill and Bodner has also reported that an analogy can powerful teaching tools because they can create new material understood by students. Many students enjoy, pay attention, and remember the analogy that their instructors provide. Although some analogies are not as effective as others. This analogy helps students to understand, visualize, and remember what they have learned in class. This information is useful for analogies synergy to give a more elaborate and complete understanding of chemistry [10]

The rest of this paper is organized as follow: Section 2 describes the proposed research method. Section 3 presents the obtained results and following by discussion. Finally Section 4 concludes this work.

## 2. Research Method

The overall research design used in this study is descriptive qualitative. This design involves collecting and analyzing qualitative data in one study to gain a more understanding of students' perspectives on analogies. Data from the qualitative phase has been used to provide a deeper understanding, because there is an opportunity to talk with participants. This qualitative study aimed (1) to identify what student know about the analogy, and (2) to identify what students think about the analogy. The participants in this study were 5 students of 11<sup>th</sup> grade at senior high school in Sleman regency, Yogyakarta, Indonesia. All participants were purposely selected in order to gain information about their understanding of the analogies. Data were collected from recordings, and interviews The researcher conducted structural interviews with 5 participants about chemistry and analogies. In the first part of the interview students answered chemistry concepts and the second part students answered about analogies. Each interview recorded. We transcribed each of the interview and then continued our analysis by reading through the interview several times to look for trends in the student opinions about the chemistry and analogies, how does the analogy benefit, and how analogies should be used in classes. As we read through the interviews, we took notes about the patterns we were seeing in the transcripts.

## 3. Results and Discussion

This section presents the results used and the proposed discussion.

### 3.1. The first part of the interview

In this part we ask student about their understanding about chemistry concepts. Based on the results of coding, all students understand what characteristics are learned in chemistry and students said that chemistry is difficult.

Elis: The higher the grade level the more difficult

Merlin: Calculating formulas, isomers, alkanes, it's a bit complicated

Sofi: What makes it difficult is sometimes we don't pay attention, if we only explain once or twice, so sometimes it's not clear

Marwa: Having difficulty because they don't know the language in chemistry, many use foreign terms

Ica: Difficulty learning chemistry because it doesn't know the concept

Based on the interview, it was concluded that what causes difficulties in studying chemistry is the existence of internal and external factors. The internal factors are concepts and chemical content that are difficult to understand such as the use of several foreign terms and formulas, while the external factor is the habit of students who do not pay attention to the teacher's explanation

Based on literature, Chemistry teachers can explain difficult and abstract concepts through analogy. Orgill and Bodner (2004) reported that an analogy can powerful teaching tools because they can create new material understood by students. Many students enjoy, pay attention, and remember the analogy that their instructors provide. Although some analogies are not as effective as others. This analogy helps students to understand, visualize, and remember what they have learned in class. This information is useful for analogies synergy to give a more elaborate and complete understanding of chemistry [10]. This method can be used as an alternative method in overcoming students' understanding deadlock, especially if students face difficulties in understanding new teaching material but have similarities in the flow of thought with previous teaching material. If learning using analogy makes students happy, then the internal and external factors can be minimized, so students will easily understand the concept and will always pay attention to the teacher's explanation.

### *3.2. The second part of interview*

#### *3.2.1. Do you know about analogy?*

In this part we ask student about their understanding about analogies. Most students said that they don't understand about analogies. They've heard the word analogy but don't understand what an analogy is. For example, Elis said the following about the analogies

Elis: I've heard analogies, but I don't know what that means.

The same answer was expressed by other participants, even for Sofi, the analogy is the word you just heard.

But, after the researcher explained about the definition of analogy, the student stated that the teacher had explained the subject matter of the law of Markovnikov using an analogy, its analogy is the state of the rich who are getting richer and the poor are getting poorer. Based on the results of interviews in the second stage, in theory students have not understood what is an analogy, but after being explained by researchers, they only realize that if they have applied in the learning system, even though not in all subject matter. It can be seen that during this time the teacher did not explicitly mention analogies, only occasionally the teacher indirectly used an analogy in one of the chemistry material taught

#### *3.2.2. What do you think if an analogy is applied to every chemical material?*

##### ***Analogies can help them learn and remember concepts in chemistry.***

Based on the results of coding, all students are interested in analogy, the following is their statement

Elis: If analogy applied in class, it can be easier, because it's more simple

Merlin: *yahh* because it was secured, what if the teacher explained that it would be easier to compare it

Sofi: Maybe it will make it easier in the lesson and understand

Marwa: The analogy will make it easier to remember, so if for example forgetting, for example the parable of the natural surroundings, if we look at it it is easy to remember, so, for example, if someone forgets, we see that there is the same one, you can immediately remember

Ica: analogy will make it easier for us to understand the concept and we can apply it to a problem

Students assume that learning chemistry with its analogy will make it easier for them to understand difficult concepts, because remembering the analogs that they already knew before will make it easier for them to remember and understand the concept of chemistry. The analogy is actually an innovation that is applied to facilitate students and lay people to easily understand chemistry. because chemistry is not a science that must be learned without any benefits that can be applied in the community. the essence of chemistry is the science whose principles and scope occur within humans and in the surrounding natural environment. through analogy we can find out and prove that what is on earth is interrelated with one another. One object or event whose form or process is unknown, will be easy to convey by relating it to objects or processes that have similar forms and processes. if educators understand this correctly, students will be interested and will continue to want to study chemistry further

In other research the use of analogies to support the learning process has been discussed. Muniz and Hoyo discussed the instructional analogies to connect core physical and chemical concepts to those at the nanoscale. They asserted: *from a qualitative study involving undergraduate chemistry students indicate that analogical transfer from core physical and chemical concepts to those at the nanoscale can be facilitated through the use of these instructional materials* [11].

According to Merlin, what is difficult when studying chemistry is when there are formulas, counting, isomers, alkanes. Application of the Teaching-With Analogies (TWA) model used in the development of the mailman analogy to retaining student learning gains in alkane nomenclature. In the mailman analogy, students are introduced to organic nomenclature of alkane and once comfortable with the analogy, are able to build on that framework to name more complex organic structure such as cycloalkane, alkenes, and alkynes [12]. With the same model, Eskandar, *et al.* have identified the effect of instructional analogies in interaction with logical thinking ability on achievement and attitude toward chemistry. During the presentation of the analogies in the classroom, students were assisted to relate the analogy concepts and target concepts by the help of some questions. By this way, the teachers contributed to the maximum participation of students in the lessons. At the end of the presented analogies the teachers explained the similarities and differences between the analogy and target concepts again [13].

Suparson and Promarak used FAR guide analogy instruction explained the effect of a catalyst and a retarder. The analogy used was riding a bicycle, riding a motorcycle, driving a car uphill, and walking up stairs. The finding indicated that this implementation was an effective means to enhance and retain students' conceptual understanding of chemical reaction rate [9]. With the same model Naseriazar, *et al.* used twelve analogies in experimental group, and have shown that the student in the experimental group significantly greater achievement than the students in control group. They said that analogies can help students visualize abstract concepts, organize their thinking about a given topic, and learn a topic meaningfully. The analogy was used, between the bohr atomis structure and the solar system as can be seen in Table 1 (adopted from [8]).

**Table 1.** Analogy the Bohr atomis and solar system

<b>Solar system</b>	<b>Structure of the atom</b>
The sun	A nucleus
Planets orbit	Electrons orbit
Planets	Electrons
The spherical shape of the sun and planets	The spherical shape of nucleus and electrons
Fixed distance from the sun to the planets	Fixed distance from the nucleus to the electrons
Helium and hydrogen as component of the sun	Proton and neutron as components of the nucleus

Target concepts and analogies used also in the science book is shown in Table 2 (adopted from [13]).

**Table 2.** Target concepts and analogies used in the science book

Target concepts	Analogies
Thomson atomic model	Raising cake
Rutherford atomic model	Football field
Bohr atomic model	Solar system
Chemical composition	Puzzle pieces
Ionic bonding	Magnetic poles

Feynman used five analogies in atoms in motion [14]

- Paramecia are like “small football-shaped things swimming back and forth”.
- Molecules in water are moving “like a crowd at a football game seen from a very great distance”.
- “if an apple is magnified to the size of the earth, then the atoms in the apple are approximately the size of the original apple”.
- An atom hitting a moving piston in a cylinder is “like a ping pong ball hitting a moving paddle”.
- Brownian motion is “like a game of push-ball”.

The instructor's main reason that their class analogy made the biochemistry concept easy to learn, analogy according to the instructor, there are two things that become easier learning, first the analogy provides an alternative explanation of the concept, which is very useful when students have not understood a more direct explanation. Second, because the concepts and phenomena discussed in the biochemical concept are abstract and complete, the language used to describe the phenomenon is also abstract and complex [15]. This is consistent with the research findings of Orgill and Bodner that most students say they like it when teachers use analogy in class. this is true students at all levels, from new students to graduate students, even though students have different reasons to like analogies and find them useful [10]. Sarantopoulos and Tsaparlis had summarized longitudinal research involving socially related use analogy in the teaching of school chemistry, and its relationship to performance and students attitude, they reported that analogy not only improved the cognitive level of students but also increased affective. They have shown that analogy is positive applies to most students [16].

### ***Good analogies are simple and in surrounding environments***

Marwa said: The analogy will make it easier to remember, so if for example forgetting, for example the parable of the natural surroundings, if we look at it it is easy to remember, so, for example, if someone forgets, we see that there is the same one, you can immediately remember

Ica: a good analogy is an analog that we often encounter

According to students that a good analogy to be applied during the learning process is an analogy that uses objects and events in the natural surroundings. because such an analogy they have understood and are often encountered in everyday life. So students only need to remember the analogy used, while the concept will be easily analyzed by themselves without having to be memorized. This is consistent with literature, a good analogy is when an analog concept can explain the concept of a target, simple, easy to remember and familiar [10]. So that there will be two different things aligned, but have the same concept or principle. One concept that will be understood will be supported by its understanding by other concepts that students have understood before science context. Analogy is classified into the following five categories, there are analog familiar, experiments, games, flow or transfer of fluid, and machine [17].

Çalik, *et al.* in [18] reviewed previous studies on teaching chemistry by analogy and conclude that teaching uses some analogies are better than teaching using a single analogy. They also suggest some key features for effective analogy instructions: (1) ensure the analogy is familiar to students, (2) map as many attributes as possible wherever possible, and (3) identify-where the analogy is broken [18]. This is consistent with the findings of Sarantopoulos and Tsaparlis who reported that we must be careful for selection of analogies has then to be made. We must examine each analogy for its

effectiveness and limitations. That the analogy must meet all the requirements for an effective analogy. The most important is the analog domains must be familiar to students [16].

To avoid mistakes when applying analogies, there needs to be systematic steps. This sequence of steps can be varied, but it is very important that all steps be taken. Because the effectiveness of the analogy is shown by students' progress in assimilating the set of relations formed between the target and the analog domain, the exploration of analog concepts is important. The idea is to take advantage of students' interests and motivations used by analogy. this can be increased by asking students to present and explain additional analogies [17]. There are several systematic applications of analogy, such as Teaching with Analogy (TWA) [20] and FAR (Focus, Action, Reflection) [19].

The systematic implementation of analogy-based learning with Teaching With Learning (TWA) is as follows: (1) Introducing the target, (2) Remind students about analogues and check what they know about analogues, (3) Identify relevant things from analog, (4) Map the similarities between analogs and targets, (5) Draw conclusions about the target, and (6) Identify comparisons that respond to analogy. The steps in the FAR guide are summarized in the following Table 3.

**Table 3.** The FAR guide for teaching with analogies

<b>Pre-lesson FOCUS</b>	
Concept	Is the concept difficult, unfamiliar or abstract?
Student	What ideas do the students already have about the concept?
Experience	What familiar experiences do students have that I can see?
<b>In-Lesson ACTION</b>	
LIKES (mapping)	Check student familiarity with the analog
	Discuss way in which the analog is like the target
	Are the ideas surface features or deep relation?
UNLIKES (mapping)	Discuss ways in which the analog is unlike the target
<b>Post-Lesson REFLECTION</b>	
Conclusions	Was the analogy clear and useful, or confusing
Improvements	What changes are needed for the following lessons?
	What changes are needed next time when i use this analogy?

If the student identifies the limitations of the analogy then the teacher can see whether the analogy has been able to transcend analogues. These examples clearly show the advantages of presenting several concept analogies simultaneously [17]. Analogy requires the selection of the world's analogs of students to help in the explanation from specific content targets. Analog sharing attributes and possible targets for the relationship to be identified. Important in presenting a good analogy some mapping evidence. This process involves systematic comparisons analog attributes and targets that are appropriate so students are fully aware of it conclusions to draw on the concept of the target being discussed. That must be considered that both analog and target have many attributes that are not shared. Good the mapping also gives some indication of where this happened so that the attribute is not divided not considered to be from the target domain [21], through mapping as in the Table 3, it will be easier for the teacher to apply and evaluate the form of analogy that is used.

#### 4. Conclusion

Analogy is one of important in chemistry learning. Most of the students like to use analogies to explain difficult concepts in their classes. Although it hasn't been applied in all chemical materials, they believe that analogies are entertaining and help them understand course information. According to the students, a good analogy to be applied during the learning process is an analog that comes from objects or events that are in the natural surroundings, so it is easy to remember. To avoid mistakes when applying the analogy there are several literatures that provide guidance that can be followed, there are TWA and FAR, for this reason, it is very important that the instructor is very clear when presenting an analogy.

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