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Teaching Chemistry Effectively with Analogy in Thai Year 10 and 12 classrooms

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Abstract. Analogy can be an effective tool to assist learning and teaching in science classrooms. Accordingly, the main research purpose of this study was how Thai chemistry teachers use analogies effectively through a professional development programme. The main research question was how to improve Thai chemistry teachers' effectiveness to teach chemistry concepts with analogies. Action research was used to generate and develop the lesson plans based on the interest, experience and competency of a group of in-service chemistry teachers who were willing to participate in the PD programme. As a result, five lesson plans were developed based on their experience of teaching in different school contexts. Several chemistry concepts to be taught included isomerism, electrophilic aromatic substitution, molecular shape, polar and non-polar molecule and length and energy bond. This paper focuses on teaching isomerism with an analogy. Although it might not be easy to seek appropriate analogies which are exactly suitable for the students, teaching with analogies did seem to be an interesting way for in-service teachers to teach chemistry. This finding might be an indication that commencing and embracing the use of analogies can be an inspiration for learning and teaching chemistry.

Keywords: earth science, educational technology, information technology, science learning

1. Introduction

One of the subjects with which students have difficulties to learn is chemistry because there are many abstract concepts requiring students to use their imagination to understand these concepts. In order to gain a deep understanding of chemistry concepts, students need to link three types of representation together, namely, the phenomenological, model and symbolic types. Consequently, to unlock students' comprehension, representing the chemistry concepts in terms of the macro, submicro and symbolic levels together is necessary to assist students' learning (Gilbert & Treagust, 2009). By using analogies that have been introduced by science educators, we can effectively teach concrete chemistry concepts (Duit, 1991; Orgill & Bodner, 2004). In addition, science educators believe that the use of analogies is one of the appropriate instructional strategies that can be used to teach all branches of science. Treagust (2001, 2015) has pointed out that analogies are believed to support students' learning of chemistry by raising students' motivation to learn the concepts by creating visualizations

to explain abstract concepts and helping students to connect scientific concepts with real life situations. As a thinking tool, analogies can help teachers be creative in explaining difficult and abstract concepts (Harrison & Coll, 2008). Furthermore, in teaching chemistry, teachers are a crucial factor in linking the use of analogies and model so that students develop a complex understanding (Coll, France & Taylor, 2005). Thus, in this study, Thai chemistry teachers were encouraged to improve the effectiveness of their teaching with analogies.

In contrast, some researchers believe that analogies can mislead and distort ideas and information if analogies are not appropriately used for explaining a concept and are unfamiliar to students (Aubusson, 2006). Therefore, teachers should be aware and concerned about using appropriate analogies in teaching. This concurs with Tyson, Treagust and Bucat (1999) who have suggested that by monitoring students' comprehension of the scientific concepts, teachers can develop their teaching strategies to facilitate their students' understanding. Therefore, when used appropriately, it seems that analogies are crucial tools to enhance students' learning and improving teachers' teaching of chemistry concepts. Furthermore, Treagust (1993) asserted that effective teaching and learning can be generated by teachers' deep understanding of the topics and knowing how to transform the content knowledge into knowledge for teaching. Thus, more opportunities of knowing how to teach effectively with analogies should be provided for teachers through this PD programme.

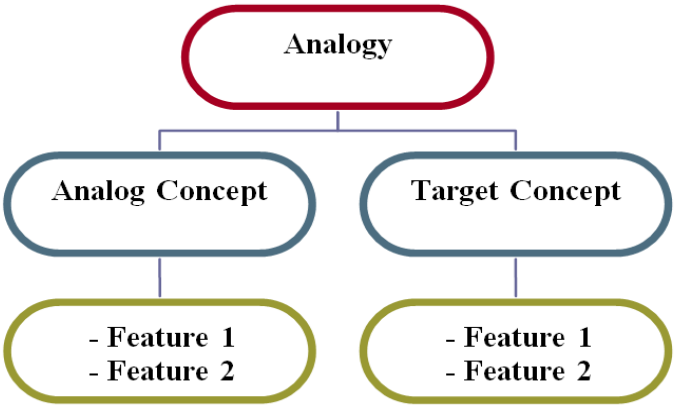


Figure 1: A conceptual representation of an analogy. (Glynn, 2015)

Both advantages and disadvantages of using analogy in teaching and learning need to be considered. To gain more benefits and limit the constraints, an interesting teaching strategy called the FAR guide (Focus-Action-Reflection) was presented as a guide for Thai teachers in the analogy workshop.

2. Methodology

This study focused on teachers' experiences when teaching and learning with analogy. The research explored chemistry teachers' perceptions and encouraged teachers to teach chemistry concepts of interest through this project. It is very important to understand and represent chemistry teachers' perceptions based on their own experiences. There is no right or wrong ways about teachers' perceptions but this study was designed to seek and explore teachers' thinking about their own teaching for future improvement. All teachers who came into this project were willing participants, desiring to improve themselves, so learning about science teaching to help each other was based on their real experiences.

2.1 *Participants*

The participants of this study were volunteers based on their interest. There were three in-service teachers who had experiences teaching chemistry concepts in year 10-12 classrooms and also they were willing to participate in this PD programme to improve themselves in teaching with analogies. Each has been teaching more than fifteen years in different high school contexts in Thailand. One of my voluntareers, who never heard about teaching with analogy before, is from Krabi city located in southern Thailand. The second teacher is from Beung Kan city located in the upper northeast of Thailand. The third teacher is from Chaiyabhum city that is located on the other side of the northeast of Thailand. They are far from Khon Kaen University approximately 1,500, 400 and 200 kilometres, respectively.

2.2 Methods of Inquiry

An appropriate research design based on research paradigms and research questions is necessary to ensure the best research outcome (Cohen, Manion & Morrison, 2013). As I noticed before, to answer the research question - How to improve Thai chemistry teachers' effectiveness to teach chemistry concepts with analogies - action research should be used to collect data about the process of developing a lesson plan. e This research question focused on chemistry teachers examining their own practice and also improving a group of in-service teachers in generating and developing the lesson plans. The qualitative data were collected to gain more in-depth understanding of the data from the three cases of in-service chemistry teachers who have experienced teaching chemistry concepts. As a case study, in-depth data were collected by evaluating lesson plans, in-depth interviews, focus groups, classroom observations (verbal and non-verbal behaviors), documents and audio-visual material (Creswell, 2012). The data were analysed in each cyclic of the process of reflection involving the implementation of potential solutions in using analogies in chemistry teaching and monitoring the impact.

At the beginning, I conducted the research by asking teachers about their educational background and interests. I spent the majority of the individual conversation asking the teachers about their opinion of analogies in general: if they like analogies, what do you know about analogies so far, what are the advantages and disadvantages of teaching with analogies, how do you use analogies in the classroom, and how analogies should be used to be effective in the chemistry class. I also asked about specific analogies that have been used in the classrooms and how they were taught. All of the qualitative data were gathered to be a portrait of this study.

An analogy is process of analysing similarities between two concepts. The familiar concept is called the analog and the unfamiliar science concept is called the target (Treagust, 2001; Glynn, 2015). A systematic comparison appears in Figure 1 (Glynn, 2015).

When presenting the workshop, the teachers were inspired by the introduction of the portrait of analogy including what is the analogy, the pros and cons of teaching with analogy, and how to teach with analogy. Moreover the teachers were challenged and enlightened with their ideas through the exemplars of teaching with analogies. The illustrations of real activities were shown to make the teaching clearer for teachers. The TWA (Teaching-With-Analogy) Model (Glynn, 1989; Glynn, 2015) was used as a framework to conduct the workshop and lead the teachers to create the lesson plans. By following the six steps are 1) introduce the target, 2) recall the analog concept, 3) identify similar features of the concepts, 4) map similar features, 5) indicate where the analog breaks down, and 6) draw conclusion about the concepts. That this is an interesting way to teach with analogies, all teachers were in agreement. As a teacher, I also agree but the difficulty is the next step. Based on my experiencing in teaching chemistry for fifteen years, it is not easy for teachers to generate the appropriate analogy

for the students and that was my worry. Hence, as a researcher, the FAR Guide, which is the interesting way in using analogy in the classrooms, was presented as a teaching guide, as shown in figure 2 (Treagust, Harrison & Venville, 1998; Harrison & Coll, 2008).

Focus	**Pre-Lesson planning**
Concept	Is it difficult, unfamiliar or abstract?
Students	What do the students already know about the concept?
Analog	Is the analog something your students are familiar with?
Action	**In-Lesson action**
Likes	Discuss the features of the analog and the science concept?
Unlikes	Draw similarities between the analog and the target or science concept.
	Discuss where the analog is unlike the science concept
Reflection	**Post-lesson reflection**
Conclusions	Was the analogy clear and useful, or confusing?
	Did it achieve your planned outcomes?
Improvements	In light of the outcomes, are there any changes you need to make next time you use this analogy?

Figure 2: The FAR guide for teaching and learning with analogies.
(Treagust, 1993; Harrison & Coll, 2008; Treagust, 2015)

In the process of generating and developing the analogy lesson plans, the action research took an important role to lead this workshop successfully by following the cycles through the plan (introducing how to teach with analogy and providing the analogy exemplary followed the FAR guide), act (generating the analogy, applying the analogy into the lesson plans), observe (discussing and sharing ideas with each other, pre-teaching with analogy, evaluating and improving the analogy) and reflect (improving and developing the analogy lesson plans) (Cohen, et. al., 2013). As a result, the analogy lesson plans were generated based on teachers' interest, as individuals experienced and shared various ideas in a small group of in-service chemistry teachers.

3. Research Findings

Not surprisingly, each of the participants embraced using analogy in their mind as an inspiration that seemed to be an optimistic view. In order to determine how these Thai chemistry teachers use analogies effectively, all data were collected which included indvidual written journals and in-depth interviews with all teachers during the workshop and also after pre-teaching and discussing with each group. This study found that teachers' previous experiences in teaching is an important factor in generating the analogy. Analogies were generated based on teachers' previous experiences, their teaching context and their background and also with students' familiar experiences. Teachers individually thought about their familiar concept and tried to develop the analog and link it with the target before bring that idea into a group to discuss and evaluate it together. After that we spent plenty of time to discover, the crossword analogy lesson plan for teaching isomerism that had been accepted to use in then chemistry classrooms.

Table 1: The crossword analogy

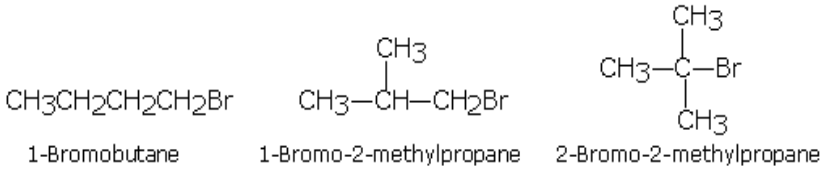
<table>
<tr><th colspan="3">The Crossword Analogy for Isomerism</th></tr>
<tr><td rowspan="4">Focus</td><td colspan="2">Concept
An isomer is a molecule with the same molecular formula but has a different structural or spatial arrangement of the atoms within molecule. These atoms or groups of atoms can be arranged in different way around the central carbon to give different molecules. As the result, isomers of the same molecule have the potential to have different physical or chemical properties and also different names.
 
1-Bromobutane | 1-Bromo-2-methylpropane | 2-Bromo-2-methylpropane</td></tr>
<tr><td colspan="2">Students
Students could not image how the isomers are different, especially, the geometric isomers, cis-isomer and trans-isomer. Students only see the information as shown in the table in the textbook but they do not really see the how the isomers have different structures.</td></tr>
<tr><td colspan="2">Analog
The crossword is basically a game which is familiar with all students. Students have the alphabet cards in their hands such as SMILE and try to make up new words along with the meaning of each word, how to pronounce, and how the write. While the alphabets have been arranging, students have been learning, motivating and working together.
  </td></tr>
<tr><td colspan="2"></td></tr>
<tr><td rowspan="4">Action</td><td colspan="2">Likes-Mapping the Analog to the Target</td></tr>
<tr><td>Analog-Crossword Game</td><td>Target-Isomerism</td></tr>
<tr><td>▪ The alphabet cards
▪ New words
▪ The different order of the alphabet cards
▪ The different pronunciations of each word
▪ The different meaning of each word</td><td>▪ Atoms or groups of atoms within molecule
▪ New isomers
▪ The different structure of molecules
▪ The different names of each isomer
▪ The different physical or chemical properties</td></tr>
<tr><td colspan="2">Unlikes-Where the Analogy Breaks Down</td></tr>
<tr><td colspan="2">▪ This is a two-dimensional representation of a three-dimensional isomer.
▪ The new word has meaning, whereas the isomer does not
▪ The atoms or groups of atoms can be arranged in different way such as cycle or chain or branch, but the alphabet cannot.
▪ There are the chemical bonding relating each atom in the molecules, whereas the alphabet cards are not there.
▪ The position of atoms or a groups of atoms and double-bond or triple-bond needs to be identified while naming the isomers.</td></tr>
</table>

Table 1 (Cont')

Reflection	**Conclusion** It is interesting that students related so well to this analogy for isomerism, although at the beginning students seemed to be worried in finding the new words.
	Improvement The crossword analogy may work well with running this game as a competition.
Content standard	The Chemistry 5 textbook of IPST.
Suggested teaching strategies	Allowing students use online dictionary that helpful and raising the crossword game interesting. STONE, SMILE, TEAM, MEAL, TIMES, and LIVE- these words can be used and easy for students to find out.

A group of Thai teachers did not deny that talk and chalk is an easy style used in the classroom especially when they have to give a basic theory of organic compounds. The chemistry textbook is a key source of learning which provides various examples and exercises.

Nui: How did you teach the isomerism before?
April: Normally, I just talked and wrote the example on the blackboard, following the textbook that usually use.
Nui: Did you teach isomerism by using the model?
April: Yeah, I sometimes do that but students still get confused and could not be clear when we arranged a methyl group or atom.
Nui: How did you get this analog?
Tanva: Honestly, we thought about something can easlily move and be easy to see how it is different when it is moved.
Nui: İs this analogy appropriate or familiar with your students?
Irin: I am sure that all students are familair with it but we might not be sure that it is appropriate with all students. This analogy is not complicated and also it is an easy one to prepare the material. We just need to prepare the cards and encourage them to play.

I also agree that the previous experience in teaching can be a key to unlocking the ideas. Based on my experience as a chemistry teacher and I have been teaching in high school (Year 10-12) since 2004, the text book tonly contains the words and overwhelming explanations. I have never seen other activities which can illustrate or demonstrate to help students understanding or build up the concreat ideas about isomerism. Discovering this analogy supported teachers' comprehensive understanding of the chemistry concept and this is crucial for generating the lesson plans to assist the learning chemistry. As Eva mentions, teachers' content knowledge is important to create an appropriate analogy that will be familiar with students. As below, Eva also supported this idea.

> *You (researcher) introduced and showed us that analogy can be a picture, model, activities or something else. We started from a big idea and think about an analogy which can be used but we failed. After discussing with a group, I realised that we need to focus on the content first and understand it and look back how we taught so far then catch up on some points. An analog cannot explain all of the target concept but just give a concrete idea or feeling through direct experience and hand it on to light all ideas up. My students already knew that isomerism is a compound which has the same*

molecule but different structures. The crossword analogy played important roles that gave more visualisation and gained deep imagination. [Eva, journal, 2015]

Teachers created the analog based on their previous experiences in class and linked it with new ideas of teaching with analogy. They have tried to map the feature of both analog and target and shared their ideas with a group that had a lively discussion. While teachers were thinking of their own analogy, some teachers asked me to explain the analogy to map it to the chemical concept. It seems that some teachers were feeling umcomfortable with the lack of content knowledge.

I cannot immidiately use your analogy [the crossword analogy] in the class because I never taught this concepts before, although I have been teaching chemistry fora long time. I need to review the content of isomerism first and also need to do some pre-teaching. That is why I asked you to give me more explanation about this concept. [Eva, interview, 2015]

More evidence from April supports the idea that knowing the content knowledge is needed. Interestingly, the text book does not contain the activities or hands-on activities to help students gain more understanding. It only shows some examples of pictures which represent the structure of compounds and verbal explanations.

After I have learnt how to teach with analogy through the example of the clay analogy activity to explain the chemical reaction.[F-Focus] I realised that I need to understand deeply about the concept which I am going to teach. I started my analogy from the hydrocarbon concepts which is my familiar concept and have been teaching for a long time. From my experience, I knew how difficult it is, some students can find out the isomerism but they might not exactly gain a deep understanding of the topic. Although I provided them more verbal explanations over and over again to help them visually and also wrote it up on the blackboard several times, that did not work well. Students just followed my steps without clearly understanding.

[A-Action]The crossword analogy would be familiar with all students. They used to play this game sevearal times in English class and I also played. Students have to make up a new word based on the alphabet cards which they have got. Then have to find out the meaning and how to pronunce the words. When we rearrange the alphabet, we get the new words, which have different meanings and pronunciations. It can be related to the isomerlism like we move the methyl group or double bond, then we got the new compounds which have the different names, structures and properties. [R-Reflection] When I introduced the crossword analogy, students seemed to gain more comprehension via the senses. [April, journal, 2015]

Knowing how to teach with analogy, especially mapping the features that are neccessary. All teachers have no doubt that they have to seek the like and unlike features of the analog and target. However, the analogy cannot represent all of the concepts, it needs to be guided. Hence, teachers need to find it out to decrease the misunderstanding in using analogy and to be certain that students are not misled to the concept.

> *Based on the lesson today about the analogy, if someone wants to teach with analogy, they need to find it out first that how to teach. You cannot bring the analogy lesson plans into the class and follow the stages of the FAR Guide, you need to know more. It is important that how much the students percieve and gain more understanding, how do they mapping and linking the features. Especially, mapping the like and unlike needs guidance. [Tanva, journal, 2015]*

Knowing how the analogy should be used is needed for effective teaching. The study found that analogy can be used to introduce the new target (science concepts) to guide and engage students' interest. And also it can be used as a visual and sharped the comprehensive understanding from the lessons. Most of teachers asserted that an abstract and difficult concept need an analogy. When I asked teachers to clarify their ideas, April responded as follows:

> *The crossword analogy was used as the second plan after I taught and described isomerism. This concept was taught by a lot of talking about it in my first teaching and I saw nothing in the eyes of my students. When the crossword analogy was used in the classroom, this concept was clearly in students' minds. [April, journal, 2015]*

All of students I spoke with also confirmed that isomerism is an abstract and the difficult concept. Students need to use their imagination to help them gain more understanding. Some students accepted that they just write down the example on the blackboard to follow the teachers without any deep understanding. But after students played the crossword analogy along with discussing with each other, it seems to be easy to understand the concept. Analogies can be used to help students learning by introducing and summarizing the concepts. And also it can be used as the illustration to connect the findings. In effective teaching with analogy, it is not only about how the analogy should be used clearly but also applying the analogy into the stages of lesson plans that need to be underlined. Moreover, the clear purpose of using the analogy will be directed to effective teaching.

Another interesting finding mentioned by all teachers is to use the analogy in pre-teaching so as to evaluate the analogy and also raise teachers' confidence before using the analogy in the classroom. Well- organized use of the analogy leads to effective teaching in classroom. As a novice researcher, I also support this idea.

> *Through discussion we have been learning a lot things, my analogies have been edited more than five times from a group but that is great, it is now complete!!, Irin said. [Irin, interview, 2015]*

Individual analogy before bringing it to a group to find out if analogy will work or not - that was helpful and brilliant, Tanva responded. [Tanva, interview, 2015]

Nui, you look like our partner rather than a researcher. And we are not only doing the research but we are sharing the experiences with each other. I was a little bit nervous when I have to teach in front of you. Because all of you are teachers but it gave me confidence about mapping the like and unlike for the analogy and target, April said. [April, interview, 2015]

Obviously, teachers gain more benefits from the pre-teaching such as sharing new perspectives, evaluating the analogy lesson plans, discussing the most effective teaching with analogy, and being well organized in using the analogy. It can also raise the teachers' confidence and, they all supported the teaching. Hence, providing an opportunity and plenty times for teachers to work with a group needs to be a consideration for conducting in-service workshops.

4. Conclusion

This study portrays how Thai chemistry teachers used analogies to effectively teach chemistry concepts with analogies. The research showed that teachers' experience is the most important aspect to create the analogy and also that teachers' comprehensive understanding of the related content knowledge is of equal importance. In bringing the analogy into a class, the familiarity of analogy for the students needs to be considered. Teachers need to be clear that when an analogy is used in the classroom that this is related to the abstract concepts or difficult concept and there is a visual image. Moreover teachers need to know how the analogy should be used and applied in the lessons plans, to be more specific how to introduce the science concept or help students to summarize the concept. And the last important view is the pre-teaching that helps teachers to have more confidence and also evaluate the effective of using the analogy before bringing them into classrooms.

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