การพัฒนาแบบจำลองทางความคิดเรื่อง รูปร่างโมเลกุลและสภาพขั้วโมเลกุล สำหรับนักเรียนชั้นมัธยมศึกษาปีที่ 4 ด้วยการจัดการเรียนรู้โดยใช้แบบจำลองเป็นฐานร่วมกับผังกราฟฟิก

The Development of Mental Model in Molecular Geometry and Polarity for Secondary 4 Students using Model-Based Learning with Graphic Organization

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Abstract

This research aims to develop student's mental models in molecular geometry and polarity for secondary 4 students using Model-Based Learning with Graphic organization. The target group of 71 students was selected. This study is qualitative research utilizing Model-Based Learning with Graphic organization designed lesson plans and the two-tier diagnostic test. The data was analyzed by percentages. The results of the study show that students held completeness and incompleteness mental models. The incomplete one is raising from the incoherence mental model including; wrong central atoms identification (28.26%), uncorrected bond polar vector addition (46.38%) and unintentional of bond polarity magnitude (5.79%). The finding could suggest that teacher need to mark the setting of Lewis structure clearly and should advance student's spatial ability and emphasis the distinctive strength of bond polarity.

Keywords: Mental Model, Model-Based Learning, Graphic organization

Introduction

Chemistry is a study of the basic component of matter as well as a study of how matter changes the form and how its properties relate to our living world. Hence, learning chemistry is learning of concepts, calculations, and ideas about the unseen object which leads problems in understanding.

Consequently, the student gets uncomplicated mental models, the model of received knowledge and experiences in mind which could express by diagrams, explanations, images and formula, regard to many topics in chemistry such as Atomic structure, Chemical Bonds and The state of matters (Khunthong, 2011; Meela and Yuenyong, 2018). This situation also found in the researcher's practicum school. An informal interview with the teacher reveals that the students also had an incomplete mental model and could not use their knowledge for solving chemistry problems. In addition, student's incorrect mental models were found when researcher had teaching in topic of atomic structure. For example, the student describes the spectrum as the changing energy of the proton, instead of the electron. Model-based learning and 5E inquiry cycle were adopted as the ideal learning method for mental model development, as this method would emphasize student-teacher communication and allow the student to fully develop in-class models (Porntip, Chatree, & Potjanart, 2014; U-ma, 2017).

The graphic organizers are media which including verbal (i.e. word and sentences) and nonverbal (i.e. line and arrow) languages, designed for more comprehensible communication with a distinctive purpose. For example, Conceptual map and Mind Mapping are notable graphic organizations for clarify the complicated content utilizing texts, boxes and arrows to show relations of each part in content. Some graphic organizations were used for specific aims such as Pyramid diagram, which could use for presenting priorities or denoting procedure. Using graphic organization with many inquiry learning methods resulted the increasing in student learning achievements (Hasan, 2017; Natedaw, Chanawat & Chet, 2017) while the graphic organizations were use as both learning tool and learning facility. Considering the complicated content of molecular geometry and polarity, the tools would use incorporate with Model-based learning to develop student mental models in molecular geometry and molecular polarity.

Objective

This research aims to develop student's mental models in molecular geometry and polarity for secondary 4 students using Model-Based Learning with Graphic organization.

Scope of Research

1. The population was 172 secondary 4 students who studying in the science-mathematics program. The students had already register Chemistry 1 at the researcher's teaching practice school in Pathumthani province. The target group was purposively selected as 71 students in the results. The criteria for the selection was the researcher's responsive classroom in which 70% of students in the class had scored 24 out of 40 in Chemistry 1 midterm examination.

2. Research Duration was 9 months, started from May 2019 to January 2020. Data collecting was performed in the semester 1/academic year 2019, began from August 10^{th} to September 2^{nd}, 2019. The duration of the collection was 24 periods or 11 hours in total.

Research Methodology

1. Research Design

The research design is a qualitative classroom action research, which employs PAOR cycle (Kemmis & Magtagart, 1998). PAOR cycle consists of 4 stages; Planning, Action, Observation, and Reflection. This method was used in the order that the researcher could revise the teaching procedure by indicating in-class incidents and aim to develop student's mental models in molecular geometry and polarity when the cycle had repeated.

2. Research Procedure

This study began the first stage of PAOR cycle, Planning. School visiting, interviewing responsive chemistry teacher (researcher's mentor teacher) and teaching student for 2 months was done to study students' backgrounds before collecting the data. Then, 6 lesson plans base on Model-based Learning and Graphic organization and research instruments were prepared.

In the Action stage, the student's mental model was examined with the researcher's developed mental model test on the topic of covalent bond. Then, the lesson plan was used with the target group. Nevertheless, the plan might be adjusted in order to cooperate with any incidents in class. The observation stage was performed at the same time by researcher, mentor teacher and other teachers as critical friends, by recording observation results on the after-teaching form. The classroom situation also recorded on video.

In the final stage, Reflection, the data from the observation stage were discussed and analyzed to evaluate the circumstance and problems in the class. Subsequently discussing the results with the mentor teacher, the suggestion and solution were used to revise the next lesson plan. The PAOR cycle would repeat until students finished the study in the last lesson plan. Then, they took the mental model test again and were asked to send the used chemistry notebook to the researcher.

3. Research Instruments

6 lesson plans in the topic of Covalent bonding and Bond length, Octet rule and Covalent compound nomenclature, Bond energy and Reaction energy, Valence Shell Electron Pair Repulsion, Bond and Molecular Polarity, and Intermolecular Force and Covalent Network Structure were prepared as experimental instruments under advisor review. All of plans were design following Model-based Learning which has 4 phases include; Generating Model, Using and Evaluating Model, Revising Model, and Elaborating Model. Otherwise, The Graphic organization was adopted as a learning tool or mental model interpreting tool.

Data collection instruments were mental model tests in the topic of covalent bond, after-teaching form, video-records, and student notebooks. The questions in the test corresponded to 8 learning objectives. The test is a two-tier diagnostic test which consists of 8 multiple choices and 4 open-ended questions. Index of Item Objective Congruence (IOC) of the test by three experts are 1 for every question. The objectives which related to this work was shown on Table 1.

Table 1 The objectives, question type and index of item objective congruence (IOC) in the diagnostic test.

Objectives	Question Type	IOC
Identify molecular geometry	Open-ended	1
Describing bond polarity and molecular polarity	Open-ended	1

4. Data Analyzation

The student’s answer in the questions of Identifying molecular geometry and Describing bond or molecular polarity from the diagnostic test was coded. Then, the student’s mental models will be analyzed using the inductive method. After considering the explanation, pictures, model and diagram, student’s mental models were categorizing into 5 groups following this table.

Table 2 The group of the mental model and corresponding description.

Pattern		Explication
Completeness	Correctness and Coherence (CR&CH)	The answer is correct and has proper explanation according to relevant principles and theories.
Incompleteness	Correctness and Incoherence (CR&ICH)	The answer is correct according to relevant principles and theories. In contrast, the explanation is inaccurate and irrelevant to the question.
Incompleteness	Incorrectness and Coherence (ICR&CH)	The answer is incorrect. In contrast, the explanation is accurate according to relevant principles and theories and relevant to the question.
Incompleteness	Incorrectness and Incoherence (ICR&ICH)	Both answer and further explanation is incorrect, inaccurate and irrelevant to the question.
Incompleteness	No Response (NR)	The student didn't provide explanations.

The data then reverified with researcher triangulation, investigating by another 2 experts. Afterward, each model was reported in percentage and the character of each mental model was described. Further investigation from the forms, the records, and the notebooks were done to extend the character of the model.

Research Finding

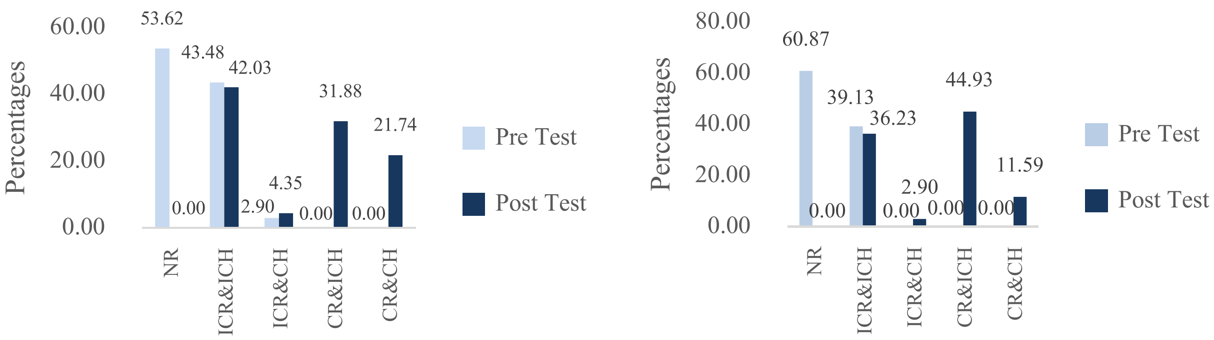

Figure 1. The percentages show classification results from 2 molecular geometry examining questions. The first chart on the right was received by categorizing data from the

identification of the molecular geometry of ClF_5, while the left chart was utilizing IOF_3 for the second question instead of ClF_5.

In these questions, the student was asked to identify the molecular geometry of certain molecules. The data from 69 students were categorized to corresponded group mental model. According to Figure 1, it concedes that most of the students held incompleteness mental model which 43.48% presented as incorrectness and incoherence mental model before studied. The increase in the correctness pattern of the mental model was found (31.88% and 21.74% in the first question,44.93% and 11.59% in the second question). In contrast, the incoherence patterns are slightly increased from the initial mental model (4.35% and 21.74% in the first question, 2.90% and 11.59% in the second question).

examining question.

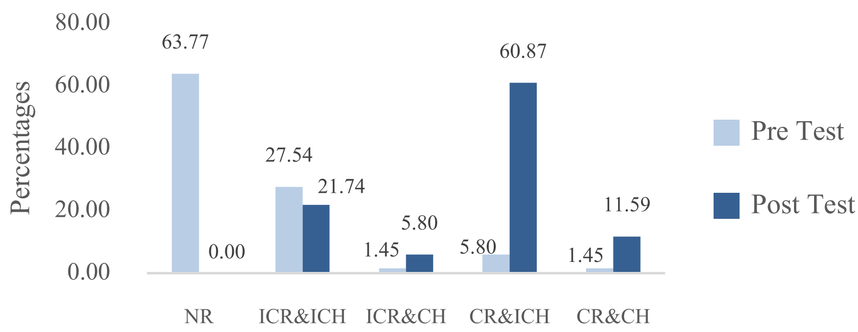

Figure 2. The percentages show classification results from a molecular polarity

To explore the mental model of molecular polarity identification, the students were required to identify the molecular polarity of CF_3H. The percentages in Figure 2 reveal that almost 34.78% of student held incompleteness mental model before studied. Also, the completeness mental model was found, before studying started, like 1.45%. The completeness mental model was increased to 11.59%. However, most students held the incompleteness mental model which could be interpreted as correctness and incoherence mental model.

Results and Discussion

The results of the study show most of the students have incompleteness mental model of molecular geometry, CR&ICH, according to figure 1. The incoherence patterns of the mental model were shown in table 1, most of the student were fell to specify the central atom, as well as showed the distorted molecular geometry (Figure 3), which in agreement with Uyulgan, Akkuzu and Alpat study (2014) and Karntarat works (2017). It may imply that the student had difficulty in forming the structure of molecules both by drawing or imagining and therefore, the mistakes were done. This rise to concern of setting the Lewis structure of molecules as students frequently asked the teacher for guidance while constructing the molecular geometry model in class. Therefore, setting the Lewis structure of molecules needs to be more emphasized in the introduction part of the lesson (Ballesster et al., 2017).

Patterns	Description
Completeness, (CR&CH)	Proper central atom, bonded atoms, and bonding type are specified. Afterward, the number of lone pair is specified by counting or drawing, the geometry was drawn and recognized by the number of bonds and lone pair electron, or by reducing the bond from non-lone pair electron geometry (18.11%). Meanwhile, the sum of the valence electron in each atom and divided by eight also use to indicate the number of bonds (Quotient) and lone pair electron (Dividing of the remainder by 2) (2.89%).
Incompleteness (CR&ICH, ICR&CH, ICR&ICH)	The molecule has wrong central atoms (28.26%) and has none or a wrong number of lone pair electrons that draw at the unsuitable location. The bonds in the model were distorted (22.46%). Furthermore, the remainder was not divided by 2 (11.59%).

Table 3 Completeness and Incompleteness patterns of Molecular Geometry Identification. The percentages indicate the number of corresponding pattern answers.

Figure 3 Pictures of the completeness and incompleteness mental model. Pictures in the box A indicate the complete model. Picture in the box B show improper structure of ClF_5 and wrong central atom of IOF_5

Most of the mental model of molecular polarity is CR&ICH. According to Table 2, almost of the incoherence pattern is mistakes in polarity vector addition. Wang (2007) described this situation as result from lacking spatial ability, i.e. the ability to understanding 3D objects from 2D form, imaging the object from a different angle and visualizing effects from operation with the object such as rotation. In consensus with the video records from the identification of the molecular geometry lesson, students used almost 2-3 minutes to construct the trigonal planar molecules from sticks and clay. In addition, the students described C-F bond is polar as C-H bond. It prefers that they are also regardless of different bond polarity. This incident also recorded and reported in the after-teaching form as students needed to urge to distinguish the unequal polarity of different bonds all the time.

Pattern	Description
Completeness, (CR&CH)	Molecular geometry with the correct central atom is the very first identity. The bond polarity of every bond then check and draw as the vector arrow. Sum of all vector needs in purpose to indicate the polarity of molecules (18.89%).
Incompleteness (CR&ICH, ICR&CH, ICR&ICH)	The vector addition of bond polarities also was not present or adjusted due to the neglect of peculiar bond polarities (46.38%). Most molecular geometry identification is improper (15.94%). Electronegativity of bonded atoms is compared, but the relation with bond polarity is not presented (5.79%).

Table 4 Completeness and Incompleteness patterns of Molecular Polarity Identification. The percentages indicate the number of corresponding pattern answers.

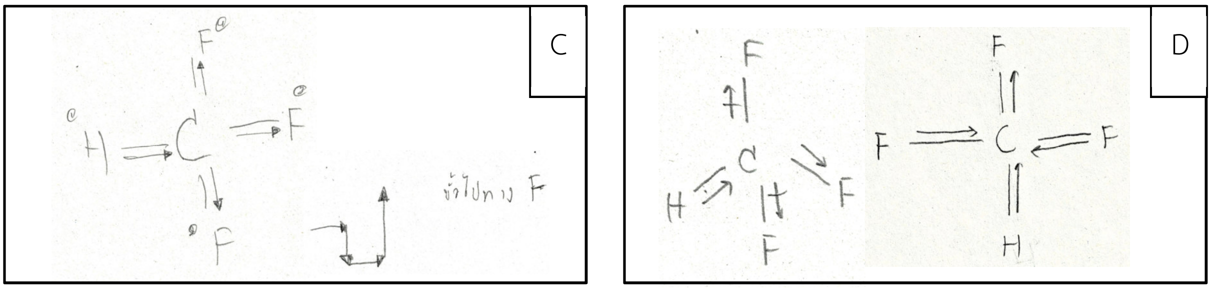

Figure 4 Pictures of the completeness and incompleteness mental model of molecular polarity identification. Pictures in the box C indicate the complete model with the vector addition. Picture in the box D show equally strength of C-H and C-F polarity.

In conclusion, the students' mental models of molecular geometry and polarity identification had been indicated in this research. With implying model-based learning and applicant of graphic organizers, the mental model was developed into the completeness and incompleteness pattern. The assessment involved the two-tier diagnostic test had shown that almost all students held correct and incoherent mental model. Characteristics of incoherence were analyzed and discuss with in-class evidence, it shows that emphasizing of setting Lewis structure is needed for completing molecular geometry identification. Deprived of spatial ability had been reported in the previous study, leads to incoherence pattern in molecular polarity identification as well as a misconception in the strength of bond polarity.

Suggestions

1. Determining Lewis structure is finely stated to let students identify molecular geometry by themselves.

2. Further explore spatial ability advancement and recognition of the distinctive magnitude of different bond polarity.

Acknowledgement

The research was supported and funded by Institution of Promoting in Science and Technology (IPST) and Project of the Promotion of Science and Mathematics talented Teachers (PSMT). The author thanks all cooperated staff and students for the kindness and helpful suggestions.

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