The Development Learning Activities Using Three Levels of Chemical Representation for Enhance Upper Secondary Students’ Organic Chemistry Concepts

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Abstract. The purpose of this study is to develop chemistry learning activities using three levels of chemical representations for enhancing upper secondary students’ organic chemistry concepts. The three levels of chemical representations are an important framework in chemistry education. Many students held misconceptions in organic chemistry because of students’ incapability to connect among the three levels of chemical representations. Development chemistry learning activities using three levels of chemical representations started by analyzing the applications of such a framework in organic chemistry lessons. The teaching strategy would follow the Life-Observation-Notation or LON approach. Chemistry learning activities were developed and received a quality examination by three experts who have experience in teaching chemistry to assess the content validity that arranged the chemistry learning activities according to the content. There are many teaching strategies used in these learning activities, such as concept map, demonstration, analogy, and hands on activities were developed. The learning activities provide abilities to relating the phenomena at a macroscopic level to a microscopic and symbolic level. The learning activities are expected to develop students’ understanding of chemical phenomena and organic chemistry concepts.

1. Introduction

Chemistry is a difficult subject to learn as being abstract and unrelated to everyday life, which often make many students misconception. The examination result in Chemistry showed the learning ability of the students. It was found that the examination score of most students were rated as medium to poor, and improvement was needed. It is because students’ incapability to connect the three levels of representations in chemistry in which the nature of chemical explanation relate to three forms of chemical representation. Johnstone [1] distinguished the three levels of chemical representation. There are three levels of chemical representation as follows: (1) macroscopic level describe properties and visible phenomena in everyday life. (2) Microscopic level explanations at the particulate such as atoms, molecules and ions, and (3) symbolic representation relate to the use of chemical symbols, formulas and equations. It helps students understanding of three levels of chemical representation, which provide students to be better understand and explain chemistry phenomena.
Research shows that students lack of translating the characteristics of chemistry between the macroscopic, microscopic and symbolic levels. The students need to understand chemical concepts by translate concepts using the macroscopic, microscopic and symbolic level [2]. Therefore, the teaching of chemistry should promote the three levels of chemical representation that might help develop students understanding of chemical phenomena, given the opportunity to experiment and discuss the observations. Students obtain more meaningful learning about chemical representations and improve their conceptual understanding [3, 4]. The teaching strategy should be used several learning activities integrate with the three levels of representation, which linked to learning outcomes and evaluations. The representational competence are very important to students’ learning in chemistry. Because students can develop not only knowledge but also need to be able to translate and transit across levels [5, 6]. And students construct their own knowledge by connecting new knowledge with existing knowledge through the three levels of chemical representation.

For this reason, it is necessary to design chemistry learning activities that address the learning style and emphasizes a role for the students to construct their own knowledge by using three levels of chemical representations in organic chemistry concepts. The organic chemistry plays an important role in the secondary school chemistry, it relies on chemical representations. However, this study focused on designing chemistry learning activities to promote students’ conceptual understanding of organic chemistry. The chemistry learning activities provide guidelines for the teachers’ to teaching organic chemistry by follow the LON approach and using three levels of chemical representations. Improve students’ ability to translate observations from macroscopic to a microscopic and symbolic level. Students are encouraged to find out for themselves about how and why chemical phenomena occur.

The purpose of the study is to develop chemistry learning activities using three levels of chemical representations for enhancing upper secondary Students’ Organic Chemistry concepts.

2. Literature review

2.1. Teaching chemistry using the Three levels of chemical representations

Ever since Johnstone [1] addressed the three levels of chemistry (macroscopic, microscopic, and symbolic) many studies have investigated how could support the construction, development, and evaluation of students’ three levels of chemical representations. The three levels of chemical representations play important roles in chemical conceptual understanding. The three level of chemical representations are ways to express phenomena, objects, events, abstract concepts, ideas, processes, mechanisms, and even systems. There are three levels of chemical representation as follows: (1) macroscopic level describe properties and visible phenomena in everyday life, (2) microscopic level explanations at the particulate such as atoms, molecular and ions, and (3) symbolic representation relate to the use of chemical symbols, formulas and equations. The learning process should be taught one after the other: macroscopic level first, structural models on microscopic level afterwards, and finally chemical symbols on the symbolic level [7]. The activities with three levels of chemical representation helps students to develop not only knowledge but also discussion structural models of matter. When relating phenomena at a macroscopic level to representations of models at different levels, the necessity exists to use more specialized language using symbols with letters and images. The learning can become meaningful when embedded in the students’ experiences with real phenomena, sequencing from concrete to abstract, using photographs and visuals, and invoking the use of representational competencies. Which can helps students improve their conceptual understanding in chemistry [8, 9, 10 and 11].

2.2. The use of Three levels of chemical representations in Chemistry Education

The three level of chemical representation involves the combination of more than one mode of representation. The successful learning of chemistry involves the constructions of mental model associations among the macroscopic, microscopic and symbolic levels for explain the chemical phenomena. Students improve their chemical conceptual understanding through interpretation of
chemical representations. The role of different modes of chemical representation making meaning in learning chemistry. From the literature review Baek et al.[12] has teaching by using MCIS to creation a scientific models and improve students’ model in evaporation and condensation of the substance. It is found that students can create scientific model, can draw a model of particles that cannot be seen and used the model to explain the chemistry phenomena. Moreover, Mitchell et at. [13] using a paper clip to represent the polymer chain and compare the reaction that students observed from experiment. As a result, using a paper clip to compare after the experiment helps students understand the reaction at the microscopic level. The chemistry learning activities used a picture describe about the movement of the particle in introduction of lesson. From the post test score the result showed that students had increased conceptual understanding. Moreover, after the students see the animation of the molecular shape, students was able to drawing molecular shape and have a better conceptual understanding [14, 15]. From the literature review above , it shows the importance of teaching chemistry with three levels of chemical representation. Resulting students being able to understand the content and improve the chemical conceptual understanding.

2.3. Teaching chemistry using the Three levels of chemical representations approach
From the relate document, Vesna Ferk Savec, Irena Sajovic and Katarina S. Wissiak Grm [16], suggest the approach to teaching chemistry base on three levels of chemical representations approach, which improve students’ understanding of chemical in everyday life and meaning of representations at the microscopic and symbolic levels. A teaching approach entitled Life – Observations – Notations (LON) was developed. The LON approach was start learning about chemical reactions from discussions about selected everyday life situations (macroscopic level). Everyday life situations are the learning process, which students understood that chemical reaction go on in everyday life. After that student present chemical phenomena with the use of models and animations of chemical reactions (microscopic level) then use symbolic notations for chemical reactions (symbolic). The learning process involves many students’ activities such as hands on experiments, construction of representations of chemical reactions with the use of models, that improved their experimental skills and gained experiences. To follow the LON approach, teachers also stated that students’ ability to connect observations from macroscopic level with their notations at microscopic and symbolic level improved.

3. Method
In this research, the chemistry learning activities using three levels of chemical representations for enhance upper secondary Students’ organic chemistry concepts were developed. This section describe the methods used in this study that consisted of the research procedures and how learning activities were adapted and developed. The details for chemistry learning activities designing process were summarized as follows:

1. Studying basic data about the three levels of chemical representations for preparation of chemistry learning activities. This step involved studying and considering relate documents for developing chemistry learning activities using three level of chemical representations for enhance upper secondary Students’ organic chemistry concepts. Related documents included the teaching using the three levels of chemical representation, upper secondary organic chemistry concepts and learning outcome.

2. Developing chemistry learning activities using three levels of chemical representations. The researcher set goals, learning outline and learning outcome. The content based on the Basic Education Curriculum A.D.2008. The content was organic chemistry in the chemistry subject for upper secondary students. After that the researcher selected teaching strategy to use in the study. It was the LON approach which students can translate concepts using the macroscopic, microscopic and symbolic level, and transit across three levels of chemical representations. There are 9 learning units with 20 periods (60 minute/period).
3. Consulting with expert who has experience in chemistry teaching to examine and verify the chemistry learning activities using the three levels of chemical representations. In this step, the chemistry learning activities validity and reliability were consulted by experts.

4. Revising the chemistry learning activities using three levels of chemical representations. This step was adjusted according to the expert suggestion.

4. Results and Discussion

The findings of the study is chemistry learning activities using three levels of chemical representations design. The researcher studied and analyzed relate document regarding the teaching using the three levels of chemical representation development, upper secondary Organic Chemistry concepts, Thai National Education Standard and learning outcome. The information was used to design chemistry learning activities. The goals of the chemistry learning activities are as the follows:

1. To facilitate students’ interest in learning chemistry with knowledge and conceptual understanding about organic chemistry.
2. To improve students’ ability to translate observation from the macroscopic, microscopic and symbolic level through the LON approach.

There were nine main topics in organic chemistry for developing the chemistry learning activities. The topic covered carbon-carbon bond, functional groups, hydrocarbon (alkane, alkene, alkyne and aromatic), organic compound with oxygen (alcohol, phenol and ether), organic compound with oxygen (aldehyde, ketone), organic compound with oxygen (carboxylic acid), organic compound with oxygen (ester), organic compound with Nitrogen (amine) and organic compound with oxygen and Nitrogen (amide). These topic were analyzed into the chemistry learning activities using LON approach that promote upper secondary students’ organic chemistry concepts. A framework of topic, activities using three levels of chemical representations follow LON approach and periods in each lesson plan was shown in Table 1.

Table 1 A framework of topic, organic chemistry concepts, activities using three levels of chemical representations design follow LON approach and periods in each lesson plan

| Main topic     | Organic chemistry concepts | Activities                                                                 | Periods |
|----------------|-----------------------------|---------------------------------------------------------------------------|---------|
| carbon-carbon bond | Carbon-carbon bond in organic compound | Life (L) This section was introduce by class discussion using pictures to show the useful which have a carbon component in everyday life. | 2       |
|                | Structural formula          | Observations (O) This section students do the graphite circuit experiment and discussion about properties of carbon (conductivity). |         |
|                | Isomer and isomerism        | Notations (N) The first activity students do the organic molecules card game. Give each player 5 cards (2 – 6 players each group). Put one of the carbons (with no double bonds) to be the starter card. The players take turns laying down cards, trying to get rid of all their cards. The first player to get rid of all their cards wins. The last card lays down must complete a molecule in |         |
| Main topic                           | Organic chemistry concepts                                                                 | Activities                                                                 |
|-------------------------------------|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| functional groups                   | - Meaning of functional groups                                                           | Life (L) This section was introduce by discussion about basic knowledge of   |
|                                     |                                           | using paracetamol and aspirin in daily life, including benefits and harmful of |
|                                     | - Types and properties of functional groups                                               | this drugs.                                                                  |
| hydrocarbon                         | - Definition and type of hydrocarbon compound                                            | Life (L) Students study about “Polymer” from the video and discussion after   |
| (alkane, alkene, alkyne and         | - The naming system, properties and reactions of alkane.                                 | watching.                                                                   |
| aromatic)                           | - The naming system, properties and reactions of alkene.                                 | Observations (O) The first activity in, students do the experiment for testing|
|                                     | - The naming system, properties and reactions of alkyne.                                 | some properties of hydrocarbon compound. The second is study the relation     |
|                                     | - Properties and reactions of aromatic hydrocarbons                                       | ship between boiling point and melting point of alkane and alkene.           |
|                                     |                                           | Notations (N) The acticity used the analogy of a mailman, who is new to an     |
|                                     |                                           | area and trying to remember the destinations of his postal route, to teach    |
|                                     |                                           | hydrocarbon nomenclature in organic chemistry.                                 |

order to win the game. The second activity is a molecule building. Students each group race to solve an organic chemistry problem and build the answer using a modelling kit.

This section was introduce by discussion about basic knowledge of using paracetamol and aspirin in daily life, including benefits and harmful of this drugs.

Observations (O) This section students do the experiment in “What’s in the drug?”. Students have to separate the mixture of drugs using chromatography techniques. Teacher prepare different brands of paracetamol and aspirin for this activity. After that discussion about the experiment’s result.

Notations (N) The first activity, students compare the structure of both paracetamol and aspirin. Then identify the functional group, which show the specific properties in molecules. The second activity is “The functional group”, students guess the name of the functional group from the given structure.

Life (L) Students study about “Polymer” from the video and discussion after watching. Observations (O) The first activity in, students do the experiment for testing some properties of hydrocarbon compound. The second is study the relationship between boiling point and melting point of alkane and alkene. Notations (N) The acticity used the analogy of a mailman, who is new to an area and trying to remember the destinations of his postal route, to teach hydrocarbon nomenclature in organic chemistry.
| Main topic | Organic chemistry concepts | Activities | Periods |
|------------|-----------------------------|------------|---------|
| organic compound with oxygen (alcohol, phenol and ether) | - The naming system, properties and reactions of alcohol.  
- The naming system, properties and reactions of phenol.  
- The naming system, properties and reactions of ester. | **Life (L)** This section was discussion about the useful of alcohol hand wash gel in daily life.  
**Observations (O)** Students do the experiment to compare the properties and reaction of different type of alcohol. Then discussion and compare the properties of alcohol phenol and ether.  
**Notations (N)** Students learn how to name alcohol phenol and ether, and summarize the knowledge in the form of concept map. | 2 |
| organic compound with oxygen (aldehyde, ketone) | - The naming system, properties and reactions of aldehyde.  
- The naming system, properties and reactions of ketone. | **Life (L)** Students watch the video about formalin in foods and discussion after watching.  
**Observations (O)** The first activity, students do the experiment testing formalin in food using a formalin test kits, and discussion about the experiment’s result. The second activity is study the pheromones of living organisms.  
**Notations (N)** Students compare the structure of aldehyde and ketone and learn how to name aldehyde and ketone. Then summarize the knowledge in the form of concept map. | 2 |
| organic compound with oxygen (carboxylic acid) | - The naming system, properties and reactions of carboxylic acid. | **Life (L)** The first activity was discussion about the acids which found in nature, such as formic acid and acetic acid. The second activity student do hands on activity to testing a real and fake vinegar (acetic acid).  
**Observations (O)** Students testing some properties of ethanol and acetic acid, and discussion about the experiment’s result.  
**Notations (N)** Students learn how to name carboxylic acid and name the 3D structure, that teacher assigned to each groups. | 2 |
Table 1 (Continued)

| Main topic                                      | Organic chemistry concepts | Activities                                                        | Periods |
|------------------------------------------------|-----------------------------|------------------------------------------------------------------|---------|
| organic compound with oxygen (ester)           | - The naming system, properties and reactions of ester.          | **Life (L)** This section students smell the perfume that teacher had prepared and guess the smell.  |
|                                                |                             | **Observations (O)** The first activity student do experiment of carboxylic acid and alcohol and discuss about the properties of the product. The second experiment was ester’s reaction. Students discuss about the hydrolysis reaction.  |
|                                                |                             | **Notations (N)** Students learn how to name ester by creates a structure model of ester that teacher assigned to each groups and name that structure.  | 2       |
| organic compound with nitrogen (amine)         | - The naming system, properties and reactions of amine.          | **Life (L)** This section discussion about the harmful of nicotine and how to measure a nicotine.  |
|                                                |                             | **Observations (O)** Students watch the video about how to detection nicotine by using a quick screening kit and discussion after watching.  |
|                                                |                             | **Notations (N)** Students learn how to name amine. Teacher showing amine formulas and students build the molecules of amine and name that structure.  | 2       |
| organic compound with oxygen and nitrogen (amide) | - The naming system, properties and reactions of amide. | **Life (L)** Students discussion about a useful of sweetener from video and their daily life.  |
|                                                |                             | **Observations (O)** This section students do the sugar testing activity. Students do experiment to test sugar and sweeteners, and discussion about the experiment’s result.  |
|                                                |                             | **Notations (N)** Students learn how to name amide by name the amide from the model that teacher assigned.  | 2       |

From Table 1, found that the researcher developed the learning activities by using three levels of chemical representations. There are 32 activities from 9 main topic of chemistry learning activity were developed to promote student’s enhance upper secondary organic chemistry concepts. The result of chemistry learning activities designing consulting with expert to examine and verify the chemistry learning activities using the three levels of chemical representations. The three experts about the chemistry learning activities validity and reliability were consulted. The activities that the researcher developed are consistent with the content and structure all activities.

The development of the learning activities using three levels of chemical representations might be improve upper secondary students’ organic chemistry concepts. There are the guidelines for teacher to
using in chemistry classroom. Use to observe the everyday phenomena through media, animation, modelling, writing formulas, symbols, chemical equations, calculations and graphs, which design for students to be able to transfer knowledge from macroscopic, microscopic and symbolic levels. That can enhance students’ creating the correct chemistry concepts.

5. Conclusion

According to the basic data, the chemistry learning activity were developed base on using three levels of chemical representations for upper secondary students. The chemistry learning activities were examined by three expert who has experience in chemistry teaching. The chemistry learning activities were composed of nine topic. The topic covered carbon-carbon bond, functional groups, hydrocarbon (alkane, alkene, alkyn and aromatic), organic compound with oxygen (alcohol, phenol and ether), organic compound with oxygen (amine), organic compound with oxygen (ester), organic compound with Oxygen (carboxylic acid), organic compound with oxygen (amide). Each topic takes 2 or 3 hours for all activities.

The teaching strategy would follow the LON approach. The LON approach is composed of three steps; 1) Life; 2) Observations; and 3) Notations. The LON approach was to start learning about organic chemistry from discussions about selected everyday life situations (macroscopic level). Which students understood that organic chemistry go on in everyday life and after that student present organic chemistry phenomena with the models and animations (microscopic level) then use symbolic notations for chemical reactions (symbolic). The learning process prefer many students’ activities such as hands on experiments, construction of representations of organic chemistry with the models. That improved their experimental skills and students’ ability to connect observations from macroscopic level with their notations at microscopic and symbolic level. The development of chemistry learning activity base on the LON approach might be enhance students’ creating the correct chemistry concept.

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