Research Article

Using STEM Workshop to Elicit Chemistry Teachers' Value of Hands-on Activity and Visualization

Patcharee Rompayom Wichaidit[1] and Sittichai Wichaidit[2*]

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ABSTRACT

This study investigated how teachers value hands-on activity and teachers' visualization including internal and external representation during performing the STEM activity. The activity expected the teachers to intuitively apply concepts of molecular polarity theory in different contexts. Sample was 152 Thai chemistry teachers who had registered for the two-day workshop entitled "the Chemistry Learning Management for Learners in the 21st Century" professional development program. Teacher's internal and external representations of solubility and polarity concepts were collected, classified, coded and analyzed by content analysis. Results revealed that 1) most teachers perceived that the hands-on activity was useful because it could help developing students' science process skills and made learning more active, 2) teachers' internal representation of the solubility and polarity concepts was illustrated to be complete (17.88%), incomplete (80.13%) and alternative conception (1.99%), and 3) an external representation mode that the teachers' usage was verbal, concrete/material and symbolic one. The result can be benefit for researchers to systematically plan further research study in the area of model and modelling of chemistry teachers because the interplay between internal and external representations during chemistry instruction is crucial and can be the indicator of how verbal external representation might be effectively used in class to scaffold students to expand their comprehension, instead of leading to the confusion by chemistry teachers themselves.

Keyword: Teacher's visualization, Teacher's internal representations, Teacher's external representations, Hands-on activity, Professional development, STEM activity

[1]Faculty of Science and Technology, Thepsatri Rajabhat University, Lop Buri, Thailand
[2]Faculty of Learning Sciences and Education, Thammasat University, Pathumthani, Thailand
[*]Corresponding author, email: inquiry@lsed.tu.ac.th

Introduction

Due to the changing in advance of technology or known as disruptive technology era, many sectors value the necessary skills need to live the fast-changing world. Students need to develop skills for better living in school as well as the future workplace. The necessary skills known as 21st century skills can be framed as ways of thinking (i.e. creativity and innovation, critical thinking, problem solving, learning to learn), ways of working (communication, collaboration), tools for working (information literacy, ICT-literacy), and ways of living in the world (global and local citizenship, life and career, personal & social responsibility, cultural awareness) [1-2]. Thailand has recently adjusted learning indicators of the core curriculum in 2017 concerning three disciplines: science, mathematics, and social study, religion and culture (Ministry of Education, 2018) and also focused on the science, mathematics and technology disciplines to equip Thai students with 21st century skills to be ready for the future workplace.

More than a decade, STEM (Science, Technology, Engineering, Mathematics) education plays an important role in teaching with disciplinary or transdisciplinary instruction [3]. Although there are several definitions of STEM education for various contexts, in this study, we used Tally's STEM framework [4] which stated that "STEM is an integrated approach to teaching and problem solving. Students are learning by asking questions, seeking information, and engineering solutions." Due to the fact that STEM education has an effect more rigorously on students' thinking and problem-solving ability as well as collaborative working that are necessary skills for 21st century learners [5]. Many countries, however, have these disciplines for its own. In the USA, for example, Purdue University has a long history of graduating teachers who specialize in science, technology, engineering, or math (STEM) courses at the high-school level [6]. In addition, The Department of STEM Education, University of Kentucky, establishes a number of graduate programs for candidates to complete the needs of individual goal and future career. Likewise, in Ireland, Trinity College Dublin offers a postgraduate certificate in 21st Century Teaching and Learning for in-service teachers. In Thailand, however, there are no directly integrated STEM major for specific need of school purpose. Thai teachers who are interested in STEM education can attend an in-service teacher professional development program.

Professional development should be continuously provided since the teachers first enrol in pre-service programs until they retire from their occupation [6]. Chemistry is one of the main branches in science disciplines. If the technology or instruments is more developed, they lead to deeper study something that has not been explored. Not only the more developed advanced content itself, but chemistry pedagogy and chemistry instructional techniques also develop over time [6]. Similar to the report of the OECD [7], the benefit of continuous professional development is to update teachers' knowledge of subject as well as skills, attitudes and approach of the new teaching technique, to enable teachers to apply changes made to curricula or teaching practice, to exchange information and expertise among teachers and others, and to help a newcomer become more confident in teaching. No matter what format of continuous professional development would be top-down or bottom-up method, its result can keep the teachers' knowledge up to date. However, the update on chemistry content knowledge (CK) or pedagogical knowledge (PK) and/or incorporated technological knowledge (TK) to the professional development program should be well designed and closely aligned with the nature of chemistry knowledge and how people learned.

Chemistry is an abstract subject because several concepts in chemistry are explained at the microscopic level (e.g. electrons, orbitals, molecules, or ions) [8]. Scientists understand the world through observation, investigation and inferences, as a result the scientists then isolate specific phenomena for studying and examine its features through its simplified models and visual representation [9]. Chemistry educators have wildly accepted the notion of triplet representation in chemistry learning [8, 10]. In the past, teaching chemistry was perceived as transmitting knowledge from teachers to students which did not much sharing the ideas or discussion. Nowadays, teaching chemistry is more translocation rather than replication and knowledge is constructed by learners rather than transmitted by the teacher [11]. On the contrary, the teachers' knowledge of fundamental concepts still plays an important role in teaching chemistry because a teacher's internal concepts or representations can lead the discussion, pose questions to convey students thinking or problem solving directly toward the learning objective.

Gilbert & Eilam [12] distinguished between internal representation or mental image and external representation. The former refers to a visualization as being a representation of an object in the brain either present or absence of the object, and the latter refers to the visually perceivable models. Representation may be understood as one thing standing for another and this is especially important in teaching because the teacher often seeks to make unfamiliar familiar [11]. In addition, the students learn chemistry concepts at the molecular level which is far from direct experience; as a result, it is not surprising that the students perceive learning chemistry may be difficult [8, 11]. As the above mentions, teachers' task is apparently not an easy one. To develop students' representational competency, teachers themselves have to be fluent, proficient and efficient in these representations [9]. Therefore, there is no surprise that a number of research studies have been administered to chemistry teachers since they once were a pre-service teacher [13].

The fact that scholars mentioned the importance of teachers' knowledge or teaching practice have an effect on how they teach and students' achievement [14-18]; therefore, professional development is the most important aspect of improving chemistry teachers to value meaningful learning activity, more inquiry-based, educationally effective, and aligned with the chemistry of the 21st century. Another reason for providing the professional development program is that many in-service teachers may have already completed their training many years. The chemistry teachers need continuing professional development to relearn both content knowledge and the aligned domain-specific pedagogical knowledge [6].

Due to the internal and external representation sharing the same mental process [12], an understanding of chemistry teachers' internal representation of concept behind the target concept is crucial for chemistry teacher professional development. Therefore, this study aimed to address three research questions:

1) how do the chemistry teachers value hands-on experiment in chemistry learning?

2) what is the internal representation of a chemistry teacher elicited from the STEM learning activity?

3) what type of external representation the chemistry teachers use, during the workshop "Chemistry Learning Management for 21st Century Learners?

Context

Chemistry teaching in some countries can be performed separately while others combined with other subjects-biology, physics, earth science-and has been taught as an integrated subject. In Thailand, at the high school level (16-18 years old), chemistry is not required for all students relying on school programs. The program can be classified into several tracts. Through these programs-Gifted Science and Mathematics Program, Science, Mathematics and English Program-chemistry is a compulsory course and has been taught as a standalone subject same as other disciplines in science. On the other hands, the students focusing on learning languages (e.g. English, Japanese, Chinese, Art science and so on), chemistry has appeared as a part of fundamental science subjects. At the middle school level (13-15 years old), however, all students are faced with basic concepts in chemistry as a compulsory science subject. Topics of chemistry are presented at this level including substances and matter, elements and compounds, acids and bases solution, physical and chemical changes, separation of pure substances and mixture.

Two-day schedule of the workshop for the chemistry teachers composed of the six following topics: 1) education for the 21st century learner and role of chemistry teachers, 2) nature of chemistry knowledge and multiple representations in chemistry learning, 3) mobile application in chemistry teaching, 4) how to design chemistry instruction through m-learning and e-learning, 5) chemistry for sustainable development (bioplastic) and 6) STEM education in chemistry learning. This article reported the analysis of internal representations of chemistry teachers from the STEM activity entitled "the grease trap."

Participants

Participants of this research study were 152 chemistry teachers across the country enrolled for the PD program "Chemistry Learning Management for 21st Century Learners." The requirement of participants as to be announced was only for chemistry teachers or teachers who have taught chemistry at the high school level. Then, the questionnaire to gain basic information of participating chemistry teachers was sent via a Google Form which the teachers could access by using their own mobile phone by scanning QR code to access and respond. Items appeared in the form includes teaching experiences (years) and background knowledge in bachelor's degree. The teachers' responses are provided in the Table 1. Of the 152 chemistry teachers, 138 chemistry teachers or 90.79 % graduated chemistry major or chemistry-related branch while 14 chemistry teacher or 9.21 % graduated other major (e.g. general science, physics, biology, material science, environmental science), but they have to teach chemistry subject because of their school reasons (e.g. chemistry teacher shortage).

Table 1 Summary of teachers' participation

Teaching Experience	Bachelor's Degree		Total
	Chemistry	Non-chemistry	
Less than 5 year	48	11	59
6-10 year	52	2	54
11-15 year	12	-	12
More than 16 year	26	1	27
Total	148	14	152

STEM Activity: The Grease Trap

The purposes of using STEM activity were to stimulate teachers thinking to apply chemistry concepts during solving problem in real-life situation and work together through inquiry process leading to produce innovative product of the grease trap. The objectives of doing the grease trap activity were that the teachers should be able to identify the basis concept of polar and nonpolar substance as well as explain factor affecting the solubility of substances. Moreover, the teacher should be able to design physical model by the provided materials together with the integration of science/chemistry, mathematics, and engineering knowledge to find out a solution to solve real-life problem. Learning process was designed in align with the 5E instructional model [19] and summarized as followed.

1) Engagement phase. The chemistry teachers were engaged to the activity by using the on-air video news of trash struck in the drainpipe and cause the water flooding in Bangkok because of slow drainage. These problems are prone to occur in the big city. The teachers then worked in group to discuss what the causal factor, was what it affected to people life, and how to cope with such problem. The researchers then asked each group for sharing their thought and pinpoint to what float on the top of the water and what kind of trash sink to bottom of the drainpipe.

2) Exploration phase. Due to the large number of teachers, the teachers were then divided to a group of five to eight to observe and explore what affect the solubility of substance. By the time the hands-on activity set was distributed to the group, the teachers' ideas were initially elicited through the Predict-Observe-Explain activity. This individual notion could be referred back to teachers' internal representations. The POE activity was used to bring the teachers' idea of solubility between water and vegetable oil and also what affected the solubility and what substance was on top of the mixture. The teachers did the hands-on activity, observed and recorded the result and answered to the POE worksheet.

3) Explanation phase. The teachers used their mobile phone to search information of property of water and fat (solid) or oil (liquid) and explained the result of the experiments that had just finished. The teachers then were distributed a box of a ball-and-stick molecular model. The teachers were asked to build the model of three water molecules and build one model of fatty acid, then place all four molecules on the clear white paper and give a reason why they place four molecular molecules that ways. Most teachers thought of polar and nonpolar of substance cause them whether they dissolve or not, and the identical density of substance causes the mixture float or sink with one another. The teachers then were randomly chosen to present their ideas to the whole class and recieved the feedback/questions from other teachers. The class was led to summarize the chemistry concepts of polar-nonpolar and solubility of substance. Finally, the teacher downloaded free application *Mirage: Geometrie des molecules* which can be operated by both Android and iOS and completed the questions in worksheet.

4) Elaboration phase. The teachers applied their knowledge to design the easy grease trap with provided materials (two plastic bottoms, a glue gun, one straw, a cutter). The teachers applied their knowledge of science (e.g. solubility, force and motion, polar and non-polar of substance), mathematics (e.g. measurement, calculation), and technology of mobile phone to search more information. During the design process, the teachers were working together to come up with the model of the grease trap. Then, the prototype of the grease trap was drawn and explained on the flipchart pad. Time duration of working in group process to design, test the efficiency, and revise to make it better was allowed for 1.5 hours. During the grease trap design and development, each group used their mobile phone to record the video of working process and posted the working process on Facebook closed group.

5) Evaluation phase. The chemistry teachers communicated their thought and ways of working, what they had found out, how they revised their first prototypes grease trap. The teachers discussed the environmental effect of draining the wastewater to the natural resources. Moreover, the discussion led to compare and contrast the advent grease trap and real product sold in the marketplace, and how to improve the invent one to be more effective than the previous version. The video recording of working process was then edited to be a few minutes length and posed on the Facebook closed group together with list of members.

Data Collection and Analysis

Data of how teacher value performing hands-on experiment, the internal representation of chemistry teacher, and type of external representation the chemistry teachers use were drawn from opened-end questions of the worksheet. The question asked the teachers to provoke their own ideas at the molecular level of two different polar substances mixed to each other. To response this question, the teachers should draw molecular representation of water and pentane molecules and also provided their explanation in the space. Because this was the two-day workshop, the STEM activity was scheduled in the first day. Individual teachers were assigned to complete the exercise as a homework during the first-day night and turn in the following day. Total of 152 participating teachers, only 151 teachers returned the worksheet to the researchers. By content analysis, all answers in the worksheet were carefully read, coded and classified into groups based on the educational theories support and drew a conclusion by consensus between the researchers.

Results and Discussion

Three opened-end questions were used as homework during the overnight of the first day workshop. Response of each question were analyzed and summarized the research finding as follows.

1. Teachers' value of doing hands-on experiment when teaching chemistry.

The first question stated that "how the chemistry teacher value hands-on experiment in chemistry learning?" The question intent to bring about the teachers' ideas how they value hands-on experience. Doing either hands-on activities or chemistry laboratories is not just doing it, but if the activities or labs are well-planed designed, they can lead the teacher know students' pre-knowledge and students on-going understanding of the target concepts. Results of teachers' perspective on implementing hands-on activity are illustrated as in the Table 2.

Information as in the Table 2 was presented in Figure 1 to illustrate the frequency of each reason the teachers had provided. The figure showed that most chemistry teachers' response value the hands-on activity because learning from authentic practice as well as explain changing in the macroscopic level (A1) (25.83%), developing science process skills and make learning atmosphere more active learning (A2)(29.14%), applying concept, find solutions to solve problem, making learning more meaningful (A5)(23.84%). Interestingly, there was no newcomer teacher (0-5 years) think that the role of hands-on activity was to prove scientific law and theory (A7).

Table 2 Code for teachers' response on the first question

Reason (code)	Description	Teaching Experience (years)				Total	Percentage (%)
		0-5	6-10	11-15	16+		
A1	Learning from authentic practice as well as explain changing in the macroscopic level	12	18	3	6	39	25.83
A2	Developing science process skills and make more active learning	16	16	4	8	44	29.14
A3	Doing real or hands-on activity and get directly experience	3	0	0	4	7	4.64
A4	Practice working cooperative with other students and planning before working	5	4	0	1	10	6.62
A5	Applying concept, find solutions to solve problem, making learning more meaningful	17	12	5	2	36	23.84
A6	Improving habit of scientific mind	2	0	0	1	3	1.99
A7	Prove the falsification of scientific law and theory	0	4	0	4	8	5.30
A8	Others (e.g. express the objective of the activity)	0	0	0	4	4	2.65
	Total	55	54	12	30	151	100

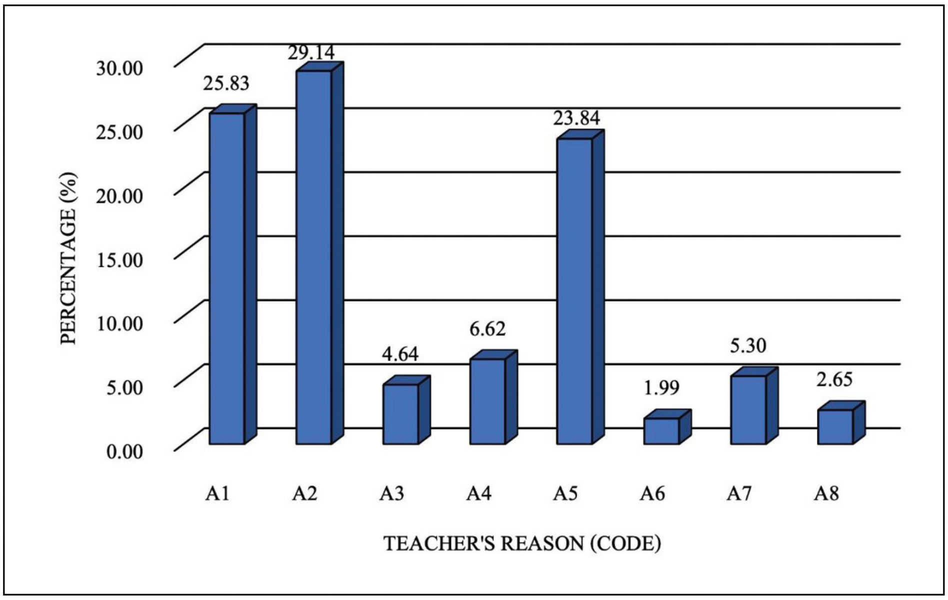


Figure 1 Percentage of Teachers' Responses

2. Internal Representation of the basic concept to explain the dissolution

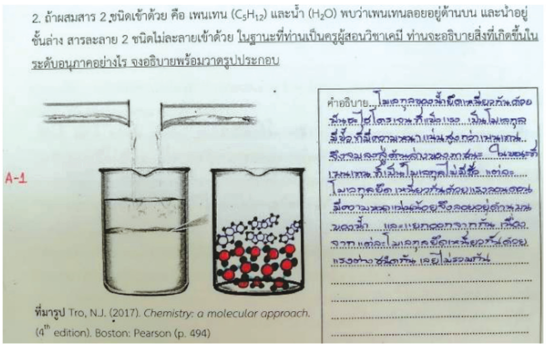
The second question of research study stated that "what is the internal representation of chemistry teacher elicited from the Grease tap STEM learning activity?" Through gain teacher internal representations at the microscopic level, the question presented at the worksheet ask the teacher to provoke their own ideas at the molecular level of two different polar substances mixed to each other.

Table 3 Code for teachers' response on the second question

Coding	Teachers' responses		Teaching Experience (Years)				
	Representation	Explanation	0-5	6-10	11-15	16+	Total
A-1*	correct	correct	6	15	-	6	27
A-2	correct	NA	-	1	-	-	1
A-3	correct(mix)	correct	16	-	3	1	20
A-4	correct	incorrect	-	1	-	-	1
B-1*	corrected symbolic	correct	13	19	6	10	48
B-2	corrected symbolic	NA	-	-	-	-	0
B-3*	correct symbolic	incorrect	-	-	1	-	1
B-4	incorrect	correct	-	-	-	1	1
C-1	NA	correct	18	17	2	10	47
C-2	NA	incorrect	-	-	-	-	0
C-3	NA	partial correction	2	1	-	2	5
Total			55	54	12	30	151

(Note: NA stands for no answer)

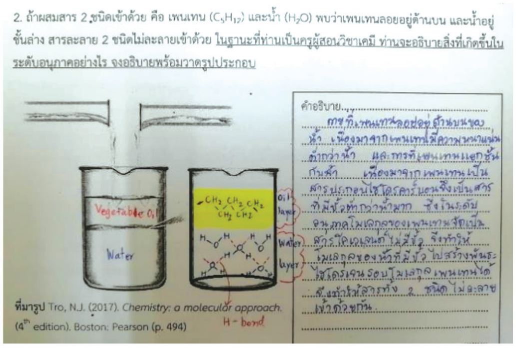
To response this question, the teachers should draw molecular representation of water and pentane molecules and also provided their explanation in the space. In order to address the research question, all responses were then coded (see also Table 3) and classified to be four groups: complete, incomplete, alternative, and no conceptions. The A code represents teachers' answers both molecular drawing and explanation. The B code reveals teachers' response both drawing and explanation, but the drawing section contains symbolic representations including either molecular formulae or line structural formulae. Finally, the code C is used for teachers' answers with none of responses on the drawing part and its explanation. All answers were afterward classified into complete (A-1), incomplete (A-2, A-3, B-1, B-2, C-1 and C-3), alternative (A-4, B-3, B-4, C-2), and no concepts. Table 3 is illustrated codes of teachers' responds and its frequency ranging from A-1 to C-3. The complete concepts of which the molecular drawing and chemistry concept explanation are composed is illustrated as in the Figure 2.



Translation : *"Water molecules bond together with strongly hydrogen bond. They are polar molecule with high density than pentane, they then sink at the bottom of the beaker while pentane is nonpolar molecule. Each molecule bond together with London force. It has low density then it floats or on top of water and also separate with water because each molecule holds different forces, then they do not dissolve with each other."*

Figure 2 Example of Complete conception (Code A-1)

The incomplete concepts showed possible these answers: drawing molecules but no providing explanation, drawing mixed representation between molecular and symbolic representation as well as providing correctly reasons, and corrected symbolic representation w/without an explanation. The incomplete conceptions, however, do not contain an evidence of any misconception but it is incomplete as expected.



Translation: *"Pentane floats on top of water because pentane has low density than water. Pentane is separated from water because the pentane is hydrocarbon which contains very low polarity than water. At the molecular level, pentane molecules are classified to be nonpolar covalence, so the polar water molecules can form a hydrogen bond around pentane molecule. It causes the two substance do not dissolve with one another."*

Figure 3 Example of alternative conception (Code A-4)

Partial correction as coded C-3 means the answer showed only macroscopic level but do not provide any reason to support such claims. For instance, vegetable oil float on top of the beaker while water is at the bottom because their density differs from each other. The answers classified to be alternative concepts are consisted of either drawing parts or explanation (Figure 3 and 4).

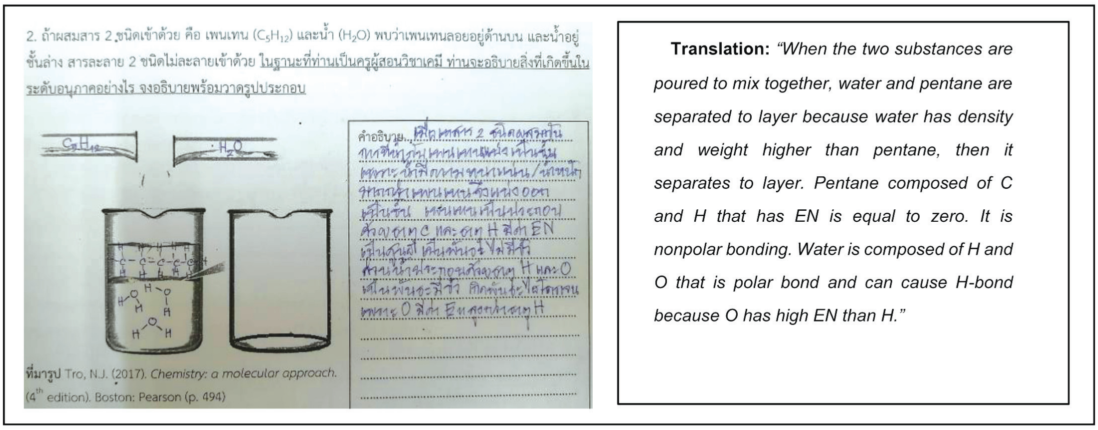
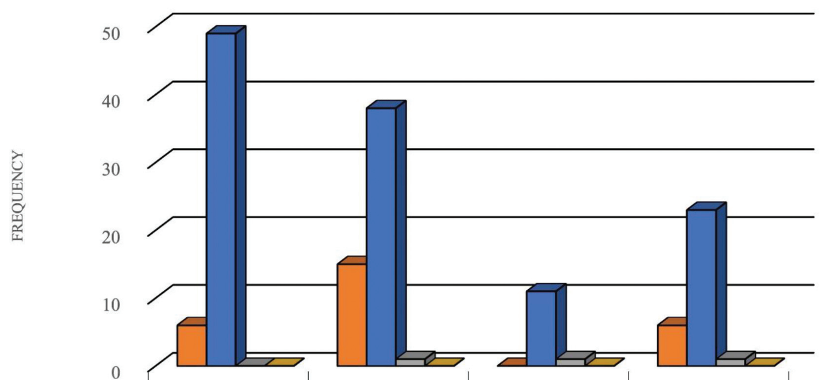


Figure 4 Example of alternative conception (Code B-3)

Finally, no conception was used to identify the answer with no responses to both drawing part and explanation part. Luckily, there is no answer classified to be no concepts. Figure 5 illustrates the frequency of responses analysis.



	0-5 years	6 - 10 years	11 - 15 years	16+ years
COMPLETE CONCEPTS	6	15	0	6
INCOMPLETE CONCEPTS	49	38	11	23
ALTERNATIVE CONCEPTS	0	1	1	1
NO CONCEPTS	0	0	0	0

Figure 5 Teachers' internal repretation analysis

Results showed that most teachers answered that question in the drawing part by using symbolic representation instead of molecular level. These results may occur because these teachers have been familiar with using symbolic representation like molecular formulae or line structure. Thai chemistry textbook during the past two decades has normally use the symbolic representation to illustrate process of chemical changing instead of explaining observed its details. Traditionally, if chemistry teaching begins with do hands-on activity or laboratory, it then will follow with the scientific concept explanation with symbolic representation. Symbolic representation is usually used to demonstrate how the substance and product are produced during the reaction. Because chemistry draws normally on a wide range of symbolic representations [10], most chemistry teachers from this study wrote the symbolic representation instead of molecular model to explain the phenomenon as well as express their ideas. In addition, this result could be simply summarized the research finding that using representations are prone to be a learning material or media helping teachers to explain more scientific concepts rather than using them to elicit students' understanding about the chemistry concepts behind the laboratory. In other word, teaching chemistry is more transmitting of knowledge rather than constructing concepts. Teachers task is not an easy one to make students grasp scientific phenomena and its representations because they are complex, comprising many components, using micro and macro levels, being explicit or implicit interactions, concrete or abstract, or a dynamic or static entities [9], However, teachers are prone to teach in the way that they were taught [20]. Teaching chemistry is most challenge and interesting to do to make diversity students with different pre-knowledge to understand the world, do like chemist, and think like chemist do.

The results also showed that there were some alternative concepts about intermolecular force. Even though only three responses were classified as alternative concepts, it was crucial that a teacher could mislead during instruction. Revealing core misconceptions in science and some reasons for them not only brought about a fundamental advancement in teaching complex phenomena [21-22] but also probably increased the need for VRs to help overcome some of the basic misconceptions [9].

3. External Representation Teachers' Usage

The third research question said that "what type of external representation the chemistry teachers use." The intension of this research question would like to see how teachers relate their own internal representation and external representation usage. The question of the worksheet stated that

"During chemistry learning, students are able to learn how to use representations in several forms such as pictures, models, or animation media. A number of representations come from textbooks, information enquiry, or teaching in the classroom. As a chemistry teacher, if you would like to teach a concept of molecular structure and providing a methane molecule as an example, and you can choose any online media freely (not limited to the examples shown here), what representations you preferred and what reasons you consider when choosing the representations?"

Results of the teachers' response on worksheet were coded and classified to two main types (*i.e.* A and B). The abbreviate A means that the teachers use the external representation with sub-category 1-5 while the B means that the teachers said that they did not use any external representation, only verbal explanation was delivering the content to their students. Results of the content analysis are illustrated as in the Table 4.

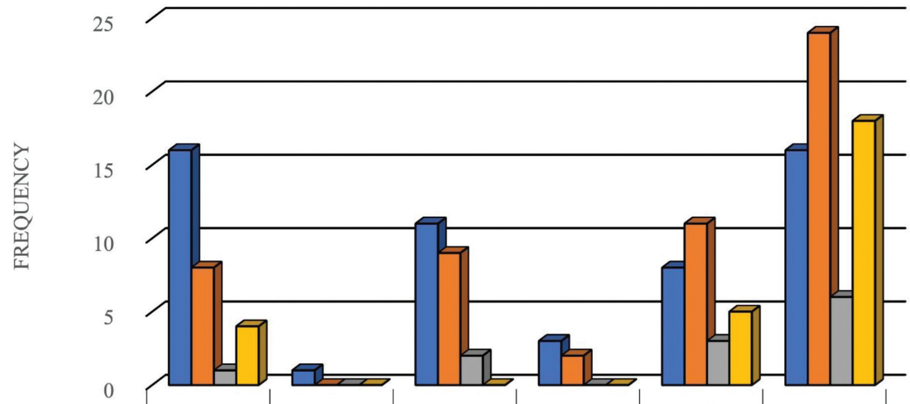
Table 4 Code for teachers' response on the second question

Type	Code	Teaching Experience (Years)				Total
		0-5	6-10	11-15	16+	
A	A-1	16	8	1	4	29
	A-2	1	0	0	0	1
	A-3	11	9	2	0	22
	A-4	3	2	0	0	5
	A-5	8	11	3	5	27
			Total			84 (56.76 %)
B	B	16	24	6	18	64 (43.24 %)
		55	54	12	27	148(100 %)

(N = 147) missing response = 1

Note: A-1 Ball-and-stick model, A-2 Line angle, A-3 Augment reality, A-4 others (color pen, balloon, YouTube, animation), A-5 combine at least two types of representations

The results showed that eighty-four teachers (or 56.76%) used representations (i.e. a ball-and-stick model, line angle model, augment reality, color pen, balloon, YouTube, animation) together with their verbal explanation. Noticeably, highly to sixty-four teachers (43.24%) did not use any representations, only verbal explanations were tools to deliver the content to their students.



	A-1	A-2	A-3	A-4	A-5	B
0-5 YEARS	16	1	11	3	8	16
6-10 YEARS	8	0	9	2	11	24
11-15 YEARS	1	0	2	0	3	6
16+ YEARS	4	0	0	0	5	18

Figure 6 Teachers' external representation analysis

Consider type of representations the teachers have adopted, the ball-and-stick model (A-1), augment reality (A-3), and combination of two representations (A-5) are more comfortable for teachers to implement during the instruction while the line angle (A-2) and others (A-4) representations are less preferred. These may be because the line angle model is proper to represent molecular shape and bond angle. Its concise molecule/atom bond with the central atom. It may cause the high school students do not understand any other related concept. The ball-and-stick model, on the other hand, is not expensive and touchable model as well as the teachers are more familiar with. Moreover, the students can feel of the bonding between atoms and they can have direct experience of connecting the different types of bond (i.e. single, double, or triple bonds) in particular molecules. During working with the physical ball-and-stick model, the teachers can observe and ask question probing students current understanding of concepts. However, the disadvantage of the ball-and-stick model due to its static model; then, it can cause students thinking that the bonded electrons are static, or they are not moving, and also the bond length is equal for all type of bonds. The benefit of using balloons is that it illustrates the electron pair repulsion according to the VSEPR theory which causes different molecular shapes. The limitation of using balloon, however, is that if the central atom has both lone pair electrons and paired electron, it cannot show the different strength between the electron paired repulsion. Lone pair electron repulsion is greater than paired electron repulsion. Finally, the color pens which is very cheap and easy to find are advantages in terms of visualizing the direction of different type of bond. The color pens are used in two different types. First, the teachers use the color pens or pencils to show bond directions in the space and to provide verbal explanation. The benefit of using color pens at this sense is much rely on the ability of teachers when explaining verbally a chemistry concept. If the teachers hold clear concepts and understand how to use color pens effectively, the instruction is much productive. On the contrary, if the teachers hold misconception and provide only their explanation, it can lead students form alternative conception. Second, the teachers assign students to use the color pens draw molecular structure or how atom bond in particular molecule. At this sense, the benefit of using color pens is using different color to represent different types of bond. Color can help students notice the different bond types or atoms. Nevertheless, the color drawing can show only 2D and it cannot show the 3D; then, the students who are struggle with imagination at the 3D level of molecule may not understand the target concept that the teacher try to teach.

Based on the external representation proposed by Gilbert and Eilam [12], five generic modes of external representation produced in terms of media can be verbal mode, concrete/material mode, visual mode, gestural mode, and symbolic mode. External representation from the research result can be summarized as verbal mode, concrete/material mode (i.e. ball-and-stick model, line angle model, augment reality, color pen, or balloon), and symbolic mode (i.e. chemical equation, chemical formula). Teachers' external representation is much related to their own internal representation. If the teacher correctly holds internal representation or concepts, they then can express external representation especially verbal mode correctly. Moreover, they are capable of selecting learning materials to help students to learn abstract concepts fluency.

Conclusion and Implication

Professional development can be benefit to teachers either top-down or bottom-up process. This study explored chemistry teacher's internal and external representation during performing the STEM activity. The activity expected the teachers to intuitive apply concepts of molecular polarity theory in different context. Acting as a student, the chemistry teachers participated in the STEM activity along with the 5E Instructional learning process. Starting with video show case of clogged drains and pipes in house as well as a big city, the case was used to engage the teachers aware of environmental problem cause by human. Then, the teachers did hands-on Predict-Observe-Explain activity to elicit teachers' concepts of molecular polarity in order to predict whether the provided substances are soluble in each other and explain related scientific reasons. Results of how chemistry teacher value doing a hands-on activity in classroom revealed that, with a number of reasons, the chemistry teachers have implemented hands-on activity in a classroom. Results of chemistry teacher's internal representation of concept behind the STEM activity suggested that there were ranking from complete, incomplete, and alternative conception. In addition, chemistry teachers' external representation in term of providing reason to support external representation usage in class indicated that almost all of them used a verbal mode as well as a verbal mode with other modes of representation (i.e. concrete/material and symbolic mode).

Scholars stated that professional development should be implemented throughout teachers' career no matter what is either top-down or bottom-up format, and an advantage to chemistry as a standalone subject might be a greater concentration on the content matter and inner structure of chemistry [6]. Because of the standalone subjects, it is the ease to pull chemistry teachers across the country who are interested in the program learning together. Another benefit of the current professional development program for chemistry teachers is that some schools lack of chemistry teachers; therefore, science teachers from other fields-biology, physics, or general science-may have to assign to teach chemistry. These teachers once learned chemistry content as educational course at the university level many years ago. They can brush up the knowledge and are aware of the current trend in chemistry education. This consequently inhibits their ability to implement and operate modern teaching approaches that require contemporary scientific and pedagogical knowledge to teach at an appropriate level and with proper methodology [23]. The research results can be benefit for researchers to systematically plan further research study in the area of model and modelling of chemistry teachers, because the interplay between internal and external representations during chemistry instruction is crucial and can be the indicator of how verbal external representation might be effectively used in class to scaffold students to expand their comprehension, instead of leading to the confusion by chemistry teachers themself.

Limitation of the study

The subjects of this study come from the application from chemistry teachers across the country; therefore, the results of the study are not be able to generalize for chemistry teachers of the whole country. Another point is that the process of gaining and interpreting internal representation of chemistry teachers should be follow with the interview before judging person's alternative conception. However, due to the large number of participants as well as the process of coding, checking, and interpreting all responses took much time to complete, it was difficult to look for chemistry teachers whose responses classified as alternative conception to know more the concept they hold. The results of alternative conception then were justified by evidently appearance and agreement among raters.

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