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**Development of an Integrative
Learning Unit to Enhance
Students' Conceptual
Understanding of Dissolution
and Their Reasoning
Sophistication**

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Abstract: Chemistry education requires establishing connections between chemistry concepts and learners' experiences encountered in the real world. However, due to the abstract nature of chemistry which is regularly displayed in an isolated-fashion in classrooms, this results in the difficulty when learners utilize knowledge relationally and rationally. To ease this learning issue, a conceptually integrative learning unit incorporating chemical concepts of dissolution was developed, involving polarity, concentration, and chemical structure. The purposes of this study are three-fold. The first is to cognitively embrace students in the content in terms of factual and applied knowledge. The second is placed on the reasoning sophistication, which plays a crucial role in problem solving, decision making, and data interpretation, by classifying it into three levels: Intuition, hybrid, and analytics. The third is to explore cognitive authority reflecting forms of knowledge which students lean towards when making decision: Direct experiences (first-hand knowledge) and learning from other people (second-hand knowledge). This research study was conducted in a quantitative manner based on a pretest-posttest design with 79 upper secondary students. The results showed that there was a statistically significant increase in students' conceptual understanding in both factual and applied knowledge, after participating in the developed learning unit. In addition, over 20% of the students exhibited more sophisticated reasoning skills (i.e. hybrid or analytic level of reasoning). Furthermore, forms of cognitive authority underpinning the reasoning skills shifted from second-hand knowledge towards first-hand knowledge after participating in the learning unit, which is considered as a more scientifically appropriate form of knowledge.

Keywords: *Cognitive Authority; Dissolution; Integrative Chemistry, Reasoning Sophistication.*

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Introduction

Since education has been reformed from time to time, the new educational vision has been raised in the 21st century (Kay & Greenhill, 2010). The way of instruction has been shifted from the tradition of teacher-centered learning towards student-centered learning (Bada & Olusegun, 2015) as a model of constructivism (Piaget, 1983; Bada & Olusegun, 2015), which aims to help students build knowledge by themselves, in which individual knowledge, feelings, actions, and experiences are valued (Bretz, 2001).

In this setting of learning, students look for contextual meanings to make sense of the world, instead of listening to their teachers passively and silently (Bodner, 1986; Bretz, 2001). The role of teachers has been changed to facilitation, which creates and maintains a constructive classroom environment that promotes the construction of ideas actively. Moreover, an important characteristic of constructivist teachers is to implement knowledge connection in their classes, for instance, sharing experiences, having discussion, making concept maps, and building a big picture of concepts (Ebenezer, 1992), which is a prerequisite skill for students to achieve higher elaborative thinking (Zoller, 1999). In brief, an arrival of the constructivist model in education has changed the way of learning in classrooms. The students gain their opportunity to think in higher order and utilize their ideas to solve problems beyond the static-and-idealistic into practical-and-realistic situations preparing them with skills for dealing with problems in society (Renner & Marek, 1990).

Perspectives in Chemistry Education and Conceptual Understanding

Chemistry involves empirical investigation of matter, its properties, and how it undergoes change (Chang, 2008). Chemistry topics associate with both observable and unobservable entities (Talanquer, 2011), which can be divided into four levels, known as the Chemistry Tetrahedron (Mahaffy, 2006; Talanquer, 2011): a macroscopic level (observable phenomena), a submicroscopic level (chemistry concepts), a symbolical level (symbolic representation), and a human context level (social world).

The four levels have an emphasis to practice students a skill of knowledge application towards the real world, i.e., social impact, problem solving, and innovation (Sjöström & Talanquer, 2014). They serve as a guideline for teachers to support and facilitate students to learn with an integration of content meaningfulness, which can empower students' cognitive skills (Elmas & Geban, 2016) and increase their thinking levels (Novak, 2002). As an expansion of constructivism into the area of chemistry, the meaningfulness of the Chemistry

Tetrahedron is that it focuses students on integrative and relational thinking resulting in more conceptual understanding of factual knowledge on the boundary line between chemical and real world as knowledge and application.

Constructivism and related frameworks are not brand new in Thailand. The constructivist approach came forth a decade ago with the intention to enhance students' learning potency (Hallinger & Lee, 2011). Nevertheless, the reformation has hardly been driven into action thoroughly in Thailand. Instead, the traditional method still majorly governs Thai classrooms (Richmond, 2007; Hallinger & Lee, 2011), where students tend to passively follow their teachers' dictation and instruction (Talanquer, 2013; Kiliç & Topsakal, 2011) in a content-oriented atmosphere (Sjöström & Talanquer, 2014).

Furthermore, in chemistry, most of its content is abstract (Carter and Brickhouse, 1989). The nature of its content mostly associates with cognitive process, relational properties, and arbitrary perspectives coming from scientific experiments (Wiemer-Hasting and Xu, 2005). The abstract nature of chemistry concepts is one factor making chemistry difficult and less meaningful for students (Cervellati & Perugini, 1981; Carter and Brickhouse, 1989; Ebenezer, 1992). A typical chalk-and-talk pedagogy is unlikely to promote student to comprehend the abstract concepts effectively (Sirhan, 2007; Genc, 2013; Talanquer, 2013).

In addition, knowledge isolation is another challenge in learning chemistry with traditional methods. To be more elaborative, dissolution is a chemistry topic involving many abstract concepts i.e. solvation process, polarity, chemical structure, and concentration. According to the International Union of Pure and Applied Chemistry (IUPAC), the term dissolution refers to the formation of homogeneous phase by the mixing of two substances in which the chemical stabilizing interaction between solute and solvent, known as solvation, is involved.

A body of research points out that many chemistry teachers focus those concepts separately as if they are not related to each other (Serrano et al., 2004) Moreover, the insufficiency of applications and practices taught in classes has been reported (Khang & Greca, 1992). Therefore, the learning difficulty and knowledge isolation breaks down the relational thinking hindering students learning performance (Furió, 1996) and reasoning causality obstructing their acquisition of basic chemical knowledge (Belova & Eilk, 2015), which is the basis for further proceeding to applications.

Reasoning Sophistication

Reasoning sophistication referred to in this study is another aspect of gaining higher order thinking skill. Reasoning plays a crucial role in chemistry learning due to its reflection of individual mechanistic thought and causality (McKenzie, 2003). In chemistry educational research, a series of reasoning models have been developed, for example, in Talanquer's research studies. Talanquer (2006) began his research interest in reasoning in chemistry firstly on the use of commonsense in academic justification which is predominantly influenced by daily-life experiences. He made his further move by exploring studying about students' explanations based on the levels of causality (Talanquer, 2010).

The investigation of reasoning sophistication had been conducted in scenarios where students applied their knowledge in meaningful contexts in chemistry (Sevian & Talanquer, 2014; Heisterkamp & Talanquer, 2015). He came up with his proposal of the theoretical framework of reasoning sophistication composing of three levels: Intuition, hybrid, and analytic (Cullipher et al., 2015) in Table 1. It shows that to achieve a high academic reasoning level, basically, students should prompt their knowledge of content as a basic requirement in order to further develop a mechanistic explanation and build causal linkage (Cooper et al., 2016)

Table 1.*Summary of reasoning sophistication framework*

Level	Description
Intuition	Using personal experiences, familiarity, impression, and beliefs with but lack of disciplinary knowledge
Hybrid	Relying on content of knowledge but struggling with connection between related concepts, less consideration in data, rapid generating conclusion but whenever those ideas are questioned, students will be thrown away and find a new one.
Analytics	Managing general and specific knowledge towards given information, Weighting pros and cons of criteria, Reflection of possible contextual factors

Cognitive Authority

It is unlikely that all kinds of knowledge are assimilated by students. Alternatively, students tend to give their degree of authority to various sources of information they've encountered, and believe selectively based on their individual decisions (McKenzie, 2003; Savolainen, 2007). This is known as cognitive authority (Wilson, 1983). In 1983, Wilson separated the forms of cognitive authority into two opposite sides: First-hand knowledge and second-hand knowledge. The former is the knowledge coming from direct-and-individual perception, whereas the latter comes from other people interaction, e.g., communication, textbooks, institution (Rasoamampianina, 2012), and other possible authorized knowledge sources (Jordan, 1997).

There are many factors leading to the different degree of students' authoritative mind towards information or its sources to decide whether information is worth taking into account, for example, trustworthiness, reliability and fruitfulness (Rieh, 2002); attitude towards speakers (Fricker, 1994); and influence towards people thinking in a specific interest (Savolainen, 2007). The cognitive authority is one of the important aspects in science education It implicitly affects

the process of rationality by the degree of belief that students assign for individual information sources. It diverges students' knowledge background, starting ideas; and it can alter students' scientific thinking which is important in scientific explanation.

Research purposes and research questions

Thus, the development of a learning unit on the dissolution topic was conducted in this research study. The incorporation of Chemistry Tetrahedron is the main instructional strategy. Three pillars of research purpose were established and pursued in this learning unit, which are to examine the students' conceptual improvement, the level of students' reasoning levels, and the students' cognitive authority. They are analyzed both before and after students' participation in this learning unit, which simultaneously serve as a lens for researchers to evaluate the effectiveness of the developed learning unit.

This research is driven by the following research questions

1. Is there any statistically significant change in students' learning scores achieved before and after participating in the developed learning unit?
2. How do students change their level of reasoning sophistication after participating in the developed learning unit?
3. What are different forms of cognitive authority that students use for constructing their reasoning before and after participating in the developed learning unit?

Methodology

Research Design

The exploratory investigations of students' conceptual understanding, reasoning sophistication, and cognitive authority after performing the developed learning unit were conducted by two approaches. The statistical investigating approach was proceeded in the

conceptual understanding part by using pre-test and post-test scores adopting a one-group pretest and posttest design. The method of a case study was done for reasoning sophistication and cognitive authority parts through rubric categorization and frequency respectively. Since the investigation seeks for the robust understanding formulation from empirical manner and statistical comparison, this research study is fallen into a house of numerical measurement and coding from standardized definitions where the quantitative research design is adopted (Newman & Benz, 1998; Neuman, 2014).

Participant Setting

A total of 79 upper secondary students in Thailand voluntarily participated in this study. Consequently, the consent forms were delivered to students and their guardians. Based on the Thai chemistry curriculum from the Institute for the Promotion of Teaching Science and Technology (IPST), the concentration, polarity, and chemical structure are placed as required topics since grade 10. However, these concepts are taught without a manner of making conceptual connection. Therefore, this learning unit presents an approach with conceptual integration and meaningfulness.

The Developed Learning Unit

In the step of learning unit designation, there was an aim to provide students an opportunity to experience and experiment with the chemical concept of dissolution in a tangible way, to extend the meaningfulness of learning chemistry. An attempt was made to create connections between the chemical concepts of dissolution, including electronegativity, polarity, concentration, and chemical structure, within real world situations. The chemical substances used in this learning unit were not hazardous, and they can be typically found in department stores, i.e., permanent marker pens, CD marker pens, poster colors, shoe polish, rubbing alcohol, nail polish remover, and soybean oil. The implementation was conducted separately according to student levels (Grades 10 to 12), and the setting was done in classrooms. At the beginning of

class time, students were divided into six to seven groups per class with four to five members, then the lesson would be carried out in regard to an overview of developed learning unit shown in Table 2.

Table 2.

Overview of the developed learning unit for the implementation

Activity (Act.)	Information
Act.1 Minitower	To engage students by letting them use a predict-reason-observe step after they see videos showing about mixing water-oil, alcohol-oil, and water-alcohol-oil respectively
Concept Delivery	To use lecture with an analogical approach in order to introduce the concept to students popcorn picking is an analogue concept of solvation process in dissolution and tug of war in an analogue concept of polarity
Act.2 Reduce It	To let students investigate the effect of concentration on overall polarity of the solution by varying the concentration of rubbing alcohol and comparing its cleaning efficacy
Act.3 Remove It	To let students design and do an investigation on eliminating provided stains by using given chemical substances before discussion about the linkage between concepts of chemical structure, polarity, and concentration and applications in a sense of cleaning products

Minitower

This activity focuses on engaging students with dissolution by using soluble and non-soluble phenomena with sets of experiments: Tap water-soybean oil, soybean oil-rubbing alcohol, and tap water-soybean oil-rubbing alcohol. Student are expected to predict the outcomes and give their reasons before they do the experiment. They are then allowed to observe the mixtures that are obviously soluble, obviously non-soluble, and vaguely soluble which lead them to a topic of solvation process and further concepts.

Concept delivery

This lecture phase aims to remind students about solvation process by introducing students with popcorn-picking analogy in which solute molecules (ethanol) are surrounded by

solvent molecules (water). Whenever solute molecules can form chemical bonds (intermolecular interaction) which is stronger than the bonds between solvent molecules (intramolecular interaction), the solvent molecules take a solute molecule out from its group, then the dissolution occurs.

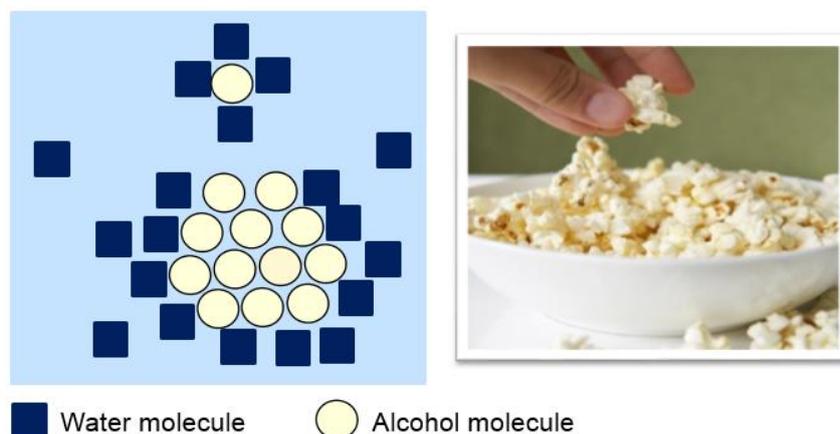


Figure 1: An analogy of solvation process and popcorn picking

The bond formation comes from the influence of molecular polarity. Individual atoms inside a molecule has different power, called electronegativity (EN), to attract electrons towards themselves. The imbalance of electron positions causes the molecule to be polar molecule according to the imbalance of partial electrical charges inside individual molecules, and vice versa.

Reduce it

This activity serves as a practice before doing the fourth and final activity, Remove It. In addition, this activity aims to introduce to students about the effect of concentration on the overall polarity of solvent. Various concentrations of rubbing alcohol are given to students. They have to soak a cotton bud in one concentration of rubbing alcohol before wiping it on permanent marker dots on a plastic sheet. They are allowed to observe the decrement of rubbing alcohol concentration which shows the lower cleaning efficiency.

Remove it

In this activity, students have to integrate the knowledge about relationship of factors that affect dissolution. They have an opportunity to and design their experiments by themselves. A plastic sheets containing 24 stained dots (eight dots per stain) are given to them. The three types of stains are poster color, CD marker, and shoe polish. The students' mission is to find conditions that can eliminate the stained dots by mixing solvents (i.e. tap water, soy bean oil, rubbing alcohol, and nail polish remover) together in various formula and concentrations. The required information, for instance, EN table, and solvent molecular structures are prepared for student beforehand.

Data Collection and Analysis

A set of tests were developed by authors and later validated by experienced Chemistry high school teachers and a Ph.D. student in Chemistry. . It consists of three parts for assessing students' conceptual understanding of dissolution and its related concepts in the form of multiple-choice questions, reasoning levels in the form of open-ended questions, and cognitive authority in the form of checklist.

This first part was tackled with the conceptual test. The test consists of 10 multiple-choice items covering the content of polarity, chemical structure, concentration, dissolution (solvation), and application (Appendix I). Out of 10, six items are associated with the levels of remembering and understanding according to the Bloom's taxonomy (1956), and the rest associated with a level of application. Students took the test before and after participating the learning, which lasted 15 minutes each. Afterward, the test scores were categorized into two groups: Factual knowledge (remembering and understanding levels) and applied knowledge (applying level onward). Finally, the scores were statistically tested by comparing their scores from the pretest and post-test using Wilcoxon signed rank test, according to the nonparametric data distribution.

Table 3.*Modified reasoning sophistication framework*

Level		Description
0	None	<ul style="list-style-type: none"> - Meaningless or senseless reasons - Reasons that are totally incompatible with the answer - Reasons based-on emotional perceptions (i.e. personal feeling, impression, familiarity, and beliefs)
1	Intuitive	<ul style="list-style-type: none"> - Individual opinion with inadequate scientific evidences - Lack of disciplinary knowledge - Reasons involving content of knowledge but struggling in knowledge connection
2	Hybrid-minded	<ul style="list-style-type: none"> - Applying partially incorrect concepts - Unawareness of using other concepts - Confusing with other concepts which is not related to the topic - Providing a correct answer with reasons from managing between the given information and their knowledge
3	Analytics	<ul style="list-style-type: none"> - Drawing conclusion from the concepts and their linkage - Reflection of potential factors affecting the answer - Showing awareness in the part which is required knowledge beyond students' level.

In the second part of the test, an open-ended question asks the students to predict an experimental result, which requires students to use their applied thoughts. This part was used for assessing their reasoning sophistication (Appendix II). The students' responses were considered thoroughly before coding to match with premade reasoning framework assigning the level of sophistication, and then an appropriate score was given to each of the responses, which was then used as numerical data for interpretation. It should be noted that the reasoning framework used in this study was partially adopted from Talanquer's framework (Cullipher et al., 2015). A modification was performed due to the differences in participant groups and their mastery in chemistry knowledge. The levels were changed into 4 levels ranged from 0 to 3, and the criteria in each level were adjusted (Table 3). The level of reasoning was then statistically

analyzed by Wilcoxon signed rank test to compare the results before and after participating the developed learning unit.

Following the open-ended question, a checklist form was used for surveying what source of knowledge that played an important role for coming up with their prediction and rationale in the reasoning part, e.g., doing experiment, teacher telling, and reading (Appendix III). The data of cognitive authority was analyzed in the forms of frequency of individual knowledge types (i.e. first-hand and second-hand knowledge).

Results

Conceptual Understanding

The scores obtained from the total number of 79 upper secondary students by using conceptual understanding test are presented in Table 4 involving factual and applied knowledge.

Table 4.

Conceptual understanding scores of upper secondary students

Measuring (Maximum score)	Pre		Post	
	Mean	Std. Deviation	Mean	Std. Deviation
Factual knowledge (6)	1.861	1.106	3.278	0.960
Applied knowledge (4)	1.076	0.844	1.772	0.696
Overall (10)	2.9367	1.324	5.051	1.176

According to Table 4, scores from posttest are higher than pretest in both sections of factual and applied knowledge.

To compare whether the posttest scores are different significantly from pretest score, an analysis was done by Wilcoxon signed rank test due to the characteristic of nonparametric statistics found from the difference between pretest and posttest scores.

Wilcoxon signed rank test is one of the statistical hypothesis tests emphasizing the comparison between two-related or matched samples, e.g., students' pretest and posttest scores from the same sample groups. The concept behind Wilcoxon signed rank test is quite close to paired Student's t-test. Unlike the paired Student's t-test, Wilcoxon Signed rank test is a non-parametric test which requires the data to be not normal distribution (Wilcoxon, 1945).

The SPSS program reported Wilcoxon signed rank test results in the form of Z scores. Z score is the standard score coming from the conversion of actual score collected from sample with mean and standard deviation. Z scores indicates whether the test results accept null hypothesis by comparing them with Z critical score in Z table. At a 95% confidence level, if Z score is less than -1.96 or greater than 1.96, the null hypothesis is rejected. The null hypothesis of Wilcoxon signed rank test is defined that there is no difference between two samples. The analysis of students' pretest and posttest score by using Wilcoxon signed rank test can be found in Table 5.

Table 5.

Wilcoxon analysis of scores in conceptual understanding test

Two-related samples (pre - post)	Z	Sig. (2-tailed)
Factual knowledge	-6.438	< 0.001
Applied knowledge	-4.696	< 0.001
Overall	-7.097	< 0.001

As seen in Table 5, it suggests that there are difference between posttest and pretest in all three sets of data: factual knowledge, applied knowledge, and overall in a positive direction with statistical significance.

It can be seen from the results that students gain more conceptual understanding about dissolution, and they tend to have better performance on factual questions.

Reasoning Sophistication

The result of reasoning level of students responded to an applied open-ended question is presented in Table 6. Only students who provided both answers and reasons were included in the analysis. It should be noted that over 94% and 50% of students in pretest and posttest respectively did answer the question but did not state their reasons.

The results from Table 6 show that there was a shift in students' reasoning level. Over 20% of students expressed a more sophisticated reasoning level after participating the developed learning unit. Around 8% of students showed a good sign of having better scientific thoughts being in hybrid and analytic levels.

Table 6.

Results of reasoning sophistication

Answer	Reasoning	No. of students who responded			
		both answer and reasons			
		Pre	Post	%Pre	%Post
Incorrect	Intuition	3	7	3.797	8.861
Correct	None	1	3	1.266	3.797
Correct	Intuition	0	11	0	13.924
Correct	Hybrid	0	6	0	7.595
Correct	Analytic	0	1	0	1.266
Summation		4	28	5.063	35.625

According to Table 6, most of students are predominantly influenced by intuition in performing scientific problem. This problem might be caused from the nature of questions which is connected to real life, but it also requires students' thinking beyond the observable world in analytical way.

Even though there were four students who performed both tests, only three of them will be presented for analysis. It is because the last student answered with totally irrelevant answers

in both pretest and posttest with ‘none’ reasoning level. The three case of responses are presented in Table 7 to Table 9.

Table 7.

The Student A’s responses in open-ended pretest and posttest

	Statement	Reasoning Level
Pretest	<i>“5% vinegar may not dissolve the permanent marker stain because we usually use rubbing alcohol in our common practice, and I have never experienced using vinegar before.”</i>	Intuition
Posttest	<i>“5% may not dissolve the permanent marker stain because it has low concentration than 75% rubbing alcohol. The lower concentration has lower polarity resulting in lower cleaning efficiency”</i>	Hybrid

In regard to pretest reasoning, student A raised ideas about general solution that linked to the scenario given in the question. The reason is tentatively limited by his own past experience, and it prevent him to give more details in other perspectives in scientific explanation. After performing activities, he tried to merge ideas of polarity concept and cleaning efficiency together to support his answer. Nonetheless, his reasons also showed a misunderstanding idea that concentration, polarity, and cleaning efficiency are direct variation. It is not completely correct because cleaning efficiency (dissolution) depends on the compatibility of both particular solute and solvent polarity level. The concentration also affects the overall polarity of mixture depended on ration of composition.

Table 8.*The Student B's responses in open-ended pretest and posttest*

	Statement	Reasoning Level
Pretest	<i>“No, it is not. Vinegar has too much low concentration, it's needed to be more concentrated looking at alcohol which has 5 times concentration more than vinegar, it still cannot dissolve the stain.”</i>	Intuition
Posttest	<i>“No because the 5% vinegar has very low concentration resulting in low solvent polarity. To increase the polarity, the concentration should be higher seen from rubbing alcohol case ... 75% v/v rubbing alcohol has higher polarity than 5% v/v vinegar.”</i>	Hybrid

Student B response showed her thought about causality between dissolution and concentration. However, there is the lack of mechanistic details in her claim besides the quantity. In the posttest, despite the inclusion of polarity in her explanation; similar to student A; she reflected an idea of direct variation between concentration and polarity.

Table 9.*The Student C's responses in open-ended pretest and posttest*

	Statement	Reasoning Level
Pretest	<i>“Vinegar can clean permanent marker stain because it is a kind of acid, so 5% may enough to clean because the normal acid can dissolve many things even though the metal.”</i>	Intuition
Posttest	<i>“5% vinegar is acid but it cannot dissolve the stain because of its low concentration ... so it cannot corrode the strain during solvation process ... the more concentration, the more power of corrosion like 75% alcohol that has more acidic property.”</i>	Hybrid

Student C expressed his causal thought of vinegar as an acidic substance. He placed the acidic property as the main factor in dissolution, but he used his familiarity of general acid property without providing scientific concepts. After performing activities, this idea of acidic

property was merged with solvation process to support his claim. Nevertheless, the dissolution provided in this scenario was not majorly affected by corrosion but the relationship of concentration, polarity, and chemical structure through solvation process.

From 79 participated students, there is only one student who provided answer and acceptable explanation to be categorized in analytic level. However, this student did not provide response in pretest, so it cannot be justify whether his reasoning level was changed. This student's response is presented in Table 10.

Table 10.

Examples of student's responses in analytic level

Reasoning	Statement	Major Characteristic
Analytics	<i>"It cannot dissolve due to the low concentration. It is because 5% vinegar is a mixture of 'pure' vinegar and water, so the lower concentration means the higher of water composes in the solvent. In my opinion, water molecules may reacts with vinegar molecules beforehand in solvation process, so it decrease the efficiency of cleaning the stain which should be reacted by vinegar molecules. Pure vinegar may have different level of polarity comparing to water but since there is high amount of water contained. This result probably ends up like in water case"</i>	<ul style="list-style-type: none"> - Contributing chemistry knowledge in a reason - Showing the awareness in the points that student felt unsure to claim confidently. - Adding more perspective in concerning about the solvent effect itself to support the answer before concluding answer again

Cognitive Authority

The results of cognitive authority categorized in first-hand and second-hand knowledge are displayed in the forms of frequency in Table 11. Students, who were selected for the analysis in reasoning sophistication, were also taken into an analysis of cognitive authority.

Moreover, students who felt unsure about their reasoning sources such as guessing were excluded in this analysis, which yielded around 2% in pretest and 30% in posttest of total students. It should be noted that students could select more than one form of cognitive authority for constructing the reasons.

Table 11.

Frequency of cognitive authority forms students used to build their reasoning

Type	Form	Frequency	
		Pre	Post
First hand	Experiment	1	15
First hand	Direct experiences / perceptions	2	7
Second hand	Teachers	4	9
Second hand	Reading	2	3
Second hand	Common sense	6	6
	Summation	15	40

According to this result along with the reasoning sophistication part, the second-handed knowledge basically governed the students' reasoning process in the forms of commonsense, which is one important factor of the intuitive mind. After participating in the learning unit, it is found that there was a decrease in proportion of commonsense but the increase in others. It shows that 'Experiment' is the forms which students frequently used for guiding their answers and explanation. It also suggests that student tend to use the first-hand knowledge (22 responses) more than second-hand knowledge (18 responses) after learning from this developed unit.

Discussion

This learning unit encourages students to learn integrally and meaningfully, which is one way to empower students' learning performance and complexity of their knowledge usage (Novak, 2002). The facilitation of knowledge connection pushes students to move beyond the limit of knowledge comprehension to step on higher on the ladder of knowledge application, which is shown as the improvement of conceptual understanding in both factual and applied

knowledge. In regard to conceptual understanding, students showed significant and positive changes of both factual knowledge and applied knowledge scores after the developed unit. This more or less affirms that the developed learning unit is effective among high school learners. However, there are always room for improvement. We realize that even though the scores increased, most of the successfully gained items were those related to recalling factual knowledge, whereas applied knowledge remained relatively low, and this is subject for further improvement. Having said that, this should not discourage us from using this kind of learning unit as we realize that leveraging applied knowledge might not be complete within a few hours. Therefore, we suggest that continuous use of learning packages that prompt students practice applying their learning to the real world, such as this, is of importance.

The reasoning part also shows that the students' reasoning levels are leveraged from the pre-intuitive and intuitive levels to the hybrid and analytic level, which also shows another side of the effectiveness of this learning unit. Nonetheless, the proportion of students who achieved the higher reasoning level is quite small (20%). We would like to point out that the reasoning sophistication is a delicate skill involving the balance of individual perceptions and logic, which requires certain time to pay attention and practice. That being said, there is no doubt why the existing research studies in this area are taken an aim towards university level and beyond, which the reasons in analytic level are potentially found. However, this study adds to our current finding that a subtle development of reasoning sophistication can be detected among school students. On top of that, the further investigation in statistical comparison could not be done due to the large difference in number of students' responses in pretest and posttest.

In regard to cognitive authority, the proportion of first-hand knowledge is shifted up after learning in this unit, especially the form of referring to actual experiments. According to the cognitive authority theory and constructivism, the learning from first-hand knowledge grants student opportunity to directly learn and experience by themselves, which helps them to

have more content understanding with longer knowledge retention time as well as the motivation to learn. Having discussed that, it does not mean the second-hand knowledge should be totally ignored because, in reality, much knowledge can and should be learned and found through second hand means. The thing that should be considered in learning science is the individual regulation in relying on information that comes from appropriate forms of cognitive authority in scientific contexts.

Conclusion

The developed learning unit focusing on chemical dissolution and its related concepts is an integration of the constructivist pedagogy to foster students to step beyond the tradition of chemistry learning and see the interconnection between chemical concepts and real life situations. It reveals that learning through the integrated methods results in achieving higher conceptual understanding and more sophisticated reasoning levels. Moreover, the students tend to alter their cognitive authority from second-hand to first-hand knowledge, which is considered more fruitful.

Learning in isolation causes students to learn knowledge in fragments, which acts as a barrier hindering student conceptions of knowledge connections and applications. Constructivist pedagogy can relieve this learning difficulty, by fostering students' higher order thinking. Teachers should put their attention on facilitation of how to assist students to build knowledge by themselves in contexts that are more constructive and meaningful.

Limitation

This research study aimed to explore the effectiveness and benefits from developed learning unit with integrated pedagogies. Even though there are positive outcomes from statistical analysis, we always keep in mind that the claim from a pre-experimental research design (one-group pretest-posttest design) may not be as strong as an experimental research

design. However, the limited number of 79 voluntary students, approximately 26 students from each grade, are frustrated to separate them into control and experiment groups.

Another unanticipated struggle comes from the void in the tests especially the written one. This problem limits us to investigate in-depth perspectives of reasoning and cognitive authority in both thinking structure breakdown and statistical comparison of development due to the instability of data.

The research design aiming to compare between learning pedagogies, e.g., traditional lecture and this integrative methods, is suggest to be done in further study. The open-ended written question is possibly redesigned. The format of semi-structured interview may be suitable for acquiring students' reasons and knowledge sources. Moreover, the interview method may increase the portion of responses as well as the collected data pool.

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Appendix I

Multiple-choice tests in the conceptual understanding part (The periodic table and electronegativity of each element are provided for students)

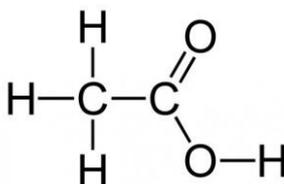
Instruction: Select the most correct answer in an answer sheet

- What is the atomic property that represent the tendency of pair electron attraction in atomic bonding?
 - Ionization Energy
 - Electronegativity
 - Electron Affinity
 - Electron Magnetism
- Which molecule has the highest polarity?
 - PCl_5
 - HBr
 - Fr
 - O_2

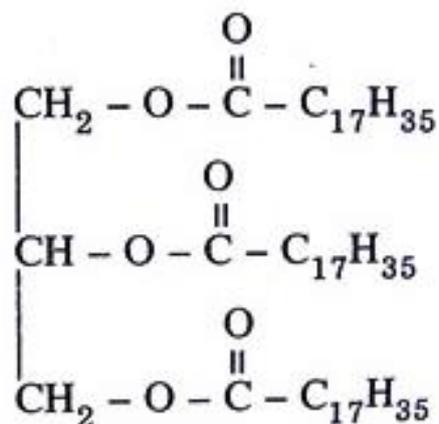
- According to the following statement, which statements are correct about water molecule (H_2O)?

A	The different of electron negativity between H-O bonding is approximately 1.2.
B	The molecular geometry of water molecule is straight line.
C	Water molecule contains both of non-polar part and polar part.
D	Oxygen atom can attract electron better than hydrogen atom.

- A, B, and C
 - B, C, and D
 - A and C
 - A and D
- The figure below is an acetic acid molecule. Which part(s) makes this molecule polar?



- Carbonyl group ($\text{C}=\text{O}$)
 - Hydroxyl group ($\text{O}-\text{H}$)
 - Both of them are correct
 - Inadequate information to answer this question
- Triglyceride is a kind of lipid or fat. Even though both polar and non-polar parts present in this molecule, why triglyceride cannot be dissolved in water?

**Triglyceride**

- The polarity of molecule is controlled by the quantity of non-polar part which presents in major portion in this molecule.
 - Triglyceride has lower density than water; it will float on the top of water. The dissolution is hardly occur due to the different in density.
 - Most areas of Triglyceride molecule are non-polar, so it is hard for water molecule to penetrate to interact with polar part in Triglyceride. The dissolution can occur, if high amount of water is used.
 - Triglyceride can actually dissolve with water. However, it dissolves in small amount which cannot be detected by human eyes.
6. According to the table below, which choice is correct?

Item	Chemical Structure	Name
A	$ \begin{array}{c} \text{O} \\ \diagup \quad \diagdown \\ \text{H} \quad \quad \text{H} \end{array} $	Water
B	$ \begin{array}{ccccccc} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \\ & & & & & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \end{array} $	Hexane
C	$ \text{N} \equiv \text{N} $	Nitrogen gas
D	$ \text{NaCl} $	Sodium Chloride

- C can dissolve in A and B
 - C and D can dissolve in A
 - D can dissolve in A and B
 - D can only dissolve in A
7. The commercial rubbing alcohol can dissolve permanent marker stain. However, when a student dilutes it with water 10 times to save the alcohol usage for cleaning the stain.

He finds that the alcohol cannot significantly dissolve the permanent marker stain. What is an explanation for this situation?

- a. The molecules of alcohol move faster when lowering concentration. The alcohol will pass the stain with less time for dissolving interaction.
 - b. Dissolution will occur when two substances have nearly equal polarity, and concentration affects the polarity of alcohol. Diluting alcohol decreases its polarity and the dissolution cannot occur.
 - c. Diluting alcohol is to add water in alcohol. Water will interact with alcohol through solvation which decrease the quantity of alcohol molecules to dissolve the stains. It results in the lowering of dissolving efficiency.
 - d. The molecules of alcohol will shrink into small size which makes them hard to form bonding with permanent marker molecules. The dissolution becomes harder to occur.
8. A student accidentally spills the ink stain on a table. He tries to use water to clean but it does not work. Later, he borrows some nail polish remover (containing high percentage of acetone) and try to clean the stain. The stain is cleaned perfectly, why the nail polish remover can clean the ink stain?
- a. The polarity level of nail polish remover is nearly equal to the ink stain.
 - b. Molecules of nail polish remover have more penetrating property than water.
 - c. Both nail polish and ink stain are more polar than water.
 - d. Nail polish remover molecules is more polar than ink stain, so they can break the bonds inside ink stain down better than water.
9. In regard to the table below, the experiment shows the matching of solutes and solvents to perform dissolving experiment. Which experiment will give positive result?

Experiment	Solute	Solvent
A	Distilled vinegar	Tap water
B	Petroleum gel	Liquid poster color
C	Shoe polish	Motor fuel
D	NaCl salt	Soybean oil

- a. A, C, and D
 - b. B and D
 - c. B, C, and D
 - d. A and C
10. According to the table below, which case comes from the effects of polarity, concentration, and chemical structure **only**?

	Case
A	Adding sugar in boiling water to make syrup
B	When adding low amount of butyl alcohol, it will mix with water very well. When adding large amount of butyl alcohol into water, it will separate into two layers.
C	Adding effervescent tablet into a glass of water
D	Adding a drop of indicator in a liquid substance then the color of mixture is changed

- A and B
- A and C
- C and D
- All of them are correct

Appendix II

Open-ended written question used in the reasoning sophistication part

In an experiment in which students add a few drops of a solvent on a dot of permanent marker stain (solute) and the results are shown below:		
Solvent	Concentration	Result
Tap water	-	Insoluble
Rubbing alcohol (Ethanol)	75% v/v	Soluble
Rubbing alcohol (Ethanol)	25% v/v	Insoluble
Distilled vinegar	5% v/v	X
Question		
What is the student's prediction of the distilled vinegar result (on an X symbol)? Please express your conceptual ideas supporting your prediction comparing with other cases		
Provided Information		
- Label from actual solvent bottles used in this experiment		
- Table of atomic electronegativity		
- Chemical structure of water , ethanol, and vinegar		

Appendix III

Knowledge source checklist used in the cognitive authority part

Instruction: Which knowledge source(s) that student use to generate explanations in the **open-ended question part**? (Student can select more than 1 choice)

_____ Experiment	_____ Teachers
_____ Reading	_____ Direct experience / perception
_____ Common sense	_____ Other: