Investigating Teachers' Understanding of the Salt Dissolution Process: A Multi-Media Approach in Education

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ABSTRACT
Animations of molecular structure and dynamics are repeatedly applied to support student comprehension in the theoretical ideas of chemistry. However, students' understanding the dynamics of the phenomena is directly related to the understanding of teachers as instructors. Therefore, this study aimed to investigate how the features of three different molecular level animations are viewed and understood by the teachers who had more than 2-years experience. Participants (n=10) are in-service science teachers, mostly high school, grouped into three groups with four participants in the first group and three people in the other two. Each group viewed short different animations and one common animation demonstrating the salt dissolution process. Teachers were asked to take pre-and post-tests to measure the influence of the animations in their understandings of the content in addition to a group discussion and an interview. The study suggests that the animations improved the content knowledge of the teachers slightly.

INTRODUCTION
Animation as an Educational Technological Tool
Due to the ubiquitous nature of technology, its influences can be seen in today's teaching, understanding, and applications in almost all disciplines. Chemistry is one of these disciplines, and recently technology applications have become a major tool in the teaching and learning processes. With the capability to animate chemical processes on the particle-level symbolization; multi-media tools such as dynamic virtual software programs play a major role in the learning-teaching process of chemistry. Specifically, since dynamic computer software bridges between macroscopic and particle-level demonstration of chemical phenomena, educators frequently apply animation and simulation in teaching chemistry concepts. Some confusion occurs about the definitions of these applications as instructional tools (Pence, 1997). *Simulations* run through mathematical formulas, which enable the tool to calculate and model the phenomena based on the subject principles. The operational definition of *simulation* is the building of a dynamic model and the study of its behavior. According to Lee (2008), as an instructional purpose, a *simulation* is a program that lets a learner interact with a computer representation not only of a scientific model of the natural or physical world but also of a theoretical framework.

Animations are presentation techniques that allow one to depict the outcomes of a simulation. A *computer animation* is "a series of visual images displayed in rapid succession on a computer screen providing the illusion of motion" (Burke, Greenbowe & Windschitl, 1998, p.1658). *Computer animations* represent and combine abstract and concrete dynamic conceptual processes at the microteaching level, thus promoting higher-order thinking skills and deeper understanding (Flick & Bell, 2000). They offer a great variety of perspectives for modeling concepts and processes. They provide a link from students' existing ideas to new knowledge acquisition. In addition, Williamson and Jose (2008) state that particulate animations come in different types: some work through mathematical equations (computational animations), some are imaginative representations of phenomena (representational animations), and others provide users with input into or control of variables (interactive animations).

Teachers' Understanding of Salt Dissolution
The process of dissolution is considerably to be more difficult to visualize since the behavior of molecules and the phenomena happening on a micro level are impossible to see. Visualizing how a solvent disappears, as molecules rearrange in the process is also hard. One can describe dissolution of salt as a breaking of the crystal lattice of salt and forming of an aqueous solution that includes the ions of the atoms and the salt molecules. An educator can animate salt dissolution process in order to demonstrate the reflection of the reality by modeling the molecules' behaviors. In addition, an educator can show the molecular scale view of all processes in a representational animation to help learners understand what happens when an ionic compound dissolves in water.

Studies stresses the importance of the teachers in enabling students to visualize natural topics occurring at micro-level to gain cognitive and conceptual understanding (Roschelle et al., 2000; Surif, Ibrahim, Mokhtar, 2012). Therefore, students' experiencing non-concrete scientific concepts by visualizing the related phenomena is important. Providing non-concrete examples at micro-level is related to the teaching strategy and it is the responsibility of the teachers since the teachers are the actual practitioners of solidifying these concepts (Stronge, 2007). Thus, relating students' difficulties with understanding the salt dissolution process to the explanations and the teaching strategies of teachers is plausible. The better teachers understand and hence introduce the topic to the students, the more comprehensively students might understand the concepts. Lastly, measuring and consequently improving teachers' understanding will increase students' understanding of materials.

Furthermore, teachers are significant factors on enabling students to visualize micro-level natural phenomena in order to provide cognitive and conceptual understanding. With the idea of Technological Pedagogical Content Knowledge (TPACK), educators have begun to overview teachers' attitudes and understanding of a content knowledge without isolating the technology and pedagogy cores of education. Technology as an educational need in this digital age and pedagogy as the practical and procedural component of education interact with one another to help teachers understand a modern effective instruction model. Teachers' attitudes and understanding of the content knowledge is critically important as the teachers should have deeper knowledge fundamentals of subject. Specifically, chemistry teachers need to provide the scientific facts and theories in addition to their practices or representations. For example, providing factual information about atomic theories should be supported by accurate representations to help student visualize the phenomena. Therefore, content in TPACK framework is essential form of teacher knowledge. Based on its importance, measuring and consequently improving teachers' understanding will increase students' learning of materials. This study aims to investigate teachers' understanding of the process in chemistry through an instructional method.

Several studies identify students' difficulties about the connection between sub-microscopic explanations and the macroscopic observations of chemical processes. The authors state that students have problems in working at sub-microscopic and macroscopic levels simultaneously and correctly (Calik, Ayas & Ebenezer, 2005, Chittleborough & Davidowitz, 2009; Gabel, 1999; Liu & Lesniak, 2006; Naah & Sanger, 2012; Smith & Metz, 1996). Moreover, some earlier studies also provided evidence that students encounter difficulties understanding salt dissolution. Cosgrove and Osborne (1981) interviewed secondary students in New Zealand to study the students' conceptions of the solution process. According to the study of Abraham, Williamson & Westbrook (1994), the ratio of understanding the dissolution concept is 27.3 % per 100 students from high school and college chemistry classes. In addition, by conducting individual interviews, Ebenezer and Erickson (1996) identified numerous examples of misconceptions on solubility in 11^{th} grade students. According to the study, students explained solubility concepts as the physical transformation from solid to liquid state or as the chemical transformation of solute.

Hence, students face a challenge in understanding the concepts at different levels. One of the things that we need to check is what teachers know and explain. To detect and get rid of the misconceptions in students' understanding of the topic, revealing the teachers' understanding of the concept is significant. The literature is insufficient to provide information about teachers' understanding of the salt dissolution process, therefore further research is needed.

Research Question

This study aims to investigate teachers' growth in understanding of the process in chemistry through an instructional method. The specific research question is: What is the difference of teachers' content knowledge on pre-to post animation viewing?

REVIEW OF THE LITERATURE

A comprehensive understanding of chemistry requires students to perceive the molecular-level imagination of the phenomena that are happening in laboratory work on a macro level. Instruction in chemistry concepts requires representing processes at particular, macroscopic, and symbolic levels; applying the integration; and moving between these three levels to achieve a deeper understanding in chemistry. Since observation of the behavior of atoms, molecules, and ions is impossible on the macroscopic level, computer applications help to illustrate some concepts by providing visualization through molecular representation of the particulate nature of matter. As a part of these applications, educators use multimedia by combining text, graphics, images, and spatial modeling in chemistry instruction.

Mayer's Cognitive Theory of Multimedia Learning describes the instructional effectiveness of animated visuals and concludes, "Students given multimedia explanations are able to build two different mental representations--a verbal model and a visual model--and build connections between them" (Mayer, 1997, p. 3). The theory emphasizes the dual (visually and verbally) processing that is required of the students. Moreover, "animations and simulations can depict the dynamic molecular world more effectively than static pictures and words because students are spared the cognitive load of having to 'mentally animate' the content" (Tasker & Dalton, 2006, p. 154). Therefore, deducing that visual information, which is the function of multimedia tools like animations, leads to improvements in the quality of learners' processing information is plausible. If animations help learners to visualize the steps of the phenomena by reflecting reality with the option of auditory narration and text explanation, then the animations yield acquisition of the knowledge better than traditional instructional strategies especially in the topics requiring visualization like many subjects in chemistry. Thus, well-prepared animations that display chemistry topics in succession should assist students' understanding of the molecular concepts.

The use of animations in the chemistry classroom environment has been shown to enhance learning (Appling & Peake, 2004; Ardac & Akaygun, 2005; Barnea & Dori, 1999; Ebenezer, 2001; Kelly, Phelps, & Sanger, 2004; Tasker & Dalton, 2006; Williamson & Abraham, 1995). For example, Ebenezer (2001) has identified computer animations as addressing the conceptualization of chemical processes in students' understanding. Additionally, two researchers in Turkey stated that the most effective way to facilitate understanding the molecular level of chemical processes is integrating animations into instruction (Ardac & Akaygun, 2005). In addition, Williamson and Abraham (1995) examined the impact of animations on students' mental models of chemistry concepts including the solution. The authors concluded that the animations help students to understand the subject matter better, and there are some functions of animations that assist constructing dynamic mental models of chemical processes.

Technological Pedagogical Content Knowledge

By the influence of digital world, students become more familiar to the technological tools. This influence is also seen in practical education since teaching is facilitated by some technological tools. As the new types of tools are emerged in the field, educators discuss technology from the perspective of pedagogy. The researchers investigate the animations, simulations, videos, and static images as new instructional strategies to understand whether the tools are applicable not only for the students but also for the teachers. Mishra and Koehler (2006) combined three domains in education (pedagogy, content, technology) to better understand how to achieve effective instruction in today's classrooms. Pedagogy in instruction and subject knowledge in science as well as the technological applications are seen as main focuses of modern classrooms. Teachers' attitudes and understanding of the combination of these three-focus become central since the teachers have inspirational role in instruction. Shulman's idea (1986) for a blend in pedagogy and content knowledge becomes more meaningful by the addition of technology core since teachers' instruction, interpretation, explanation, conceptualization of subject matter is related to instructional strategies which necessitated technological applications.

Animations from the Perspective of Teachers' Attitudes and Understanding

Teachers' perspectives on the usefulness of animations are significant factors for students' achievement. Teachers' use of animations or their attitudes towards using them is influential in the flow of the lesson and in the students' understanding of the content. One promising finding is that teachers' attitudes toward using multimedia applications have increasingly become more positive (Davidson & Ritchie, 1994; Dupagne & Krendl, 1992; Kellenberger, 1996; Reed, 1986; Wang & Holthaus, 1999; Woodrow, 1987; Yunus, Salehi, & John, 2013). According to Yunus, Salehi, and John's study (2013), 50 of 52 pre-service teachers in Malaysia believed that the use of visual aids could be effectively implemented as instructional tools and create an enjoyable learning environment. In addition, the majority of the teachers had positive perception to the use of visual aids in the classroom, such as animations, since the visual aids arouse students' motivation and help students to comprehend the topic better.

Moreover, a study carries out to investigate Ohio science teachers' perceptions of nine components of computer implementation for instructional use. The study shows that teachers' attitude toward the use of computers as teaching tool is a fundamental step in the use of computers for the educational purposes (Shiverdecker, 2012). Additionally, in the same study, the researcher discovers, "there are differences between the perceptions of teachers who have reached advanced stages of use and teachers who are at lower stages of use" (p. iii). Therefore, figuring out the teachers' understanding of computer-based instructional techniques will assist researchers in understanding students' challenges and improving the quality of the level of instruction.

Teachers' attitudes toward applying multimedia, particularly animations, also relate to the teachers' involvement in the applications. A study that investigates teachers' misconceptions or myths about the use of animations finds, "some instructors do use animations in class, but they simply play them for students with no other reference to the animation or its content. Others assign students to watch animations as homework, but never refer to them again. In some classrooms, particle-level animations are only used once or twice during the term" (Williamson, 2011, p.72).

Additionally, teachers' attitudes toward using animations in the classroom and their eliciting students' participation are significant. If the teacher offers no explanation during viewing the animation, students perceive features of the animation but may interpret the content inaccurately or may misinterpret the design of the animations. According to Williamson (2011), educators do not use animations effectively when instruction is in isolation. An instructor should be active in assisting students to comprehend the animation simultaneously with instruction.

Lastly, teachers' attitudes and views toward instruction through animations are influential whether the application is used correctly and achieves its intended purpose. The way that teachers use animations in the classroom and teachers' perception about animations reveal their understandings of the related content.

Students and teachers should use animations to teach chemistry concepts. Williamson and Jose (2009) described a number of techniques that guide the learners to form mental images of chemical phenomena at the macroscopic level. Many more research studies mentioned above state the advantages of applying animations in chemistry instruction. Specifically, although many researchers have already investigated the influence of animations on students' understanding of the salt dissolution process, few findings reveal how instructors understand using animations or how the teachers apply the animations as teaching tools in the classrooms. Since the teachers have key roles in applying the method, further studies are necessary to provide more evidence and investigate ways researchers can appropriately demonstrate the method, including how comprehension increases through the use of animations.

METHOD

Participants

The sample consisted of 10 in-service science teachers from a school district near a large urban district in the southwestern part of the United States. At the time of the study, eight participants taught high school science, and two were middle school science teachers. In addition, the teachers studied a master degree in science education during the time of this research.

The study took place when the teachers join in a pre-scheduled professional development session. All science teachers volunteered for the study; therefore, the session time was extended for the research. The teachers preferred to sit as three in one table, three on another table, and four in the other table. The groups were formed naturally according to their seating preferences. The teachers participated in all phases of the study: pre-test, animation demonstration, post-test, second animation display, group discussion, and a delayed post-test.

Measures

To clarify the design, the researcher describes the measures in three phase. The teachers completed a pre-test before viewing any animation; then they viewed the first animation (different animations for each group) and completed the first post-test (post-test 1). This was the first phase of the study. Right after completing the first phase, the teachers viewed the second animation (same animation for each group) and completed the second post-test (post-test 2). This was the second phase of the study. In this phase, the teachers also answered the question asking what the teachers would use as an instructional strategy while teaching of NaCl dissolving as the last question post-test 2. Lastly, the researcher asked the teachers to make group discussion and then answer the same question about animation as an instructional strategy (what they would use in teaching NaCl dissolving) to understand if teachers' ideas changed about using animation in their classroom. This was the last phase of the study.

The pre-and post-tests were the same in the first four questions, which focused on the content knowledge. Post-test 1 and 2 included an additional question (question 5), focused on the illustrations of the animations. Furthermore, Post-test 2 included one more extra question that pre-test and post-test 1 did not include.

The first item in pre-post tests was a drawing question about molecular-level happenings before and after the dissolution process. The next two questions asked written explanations about the salt dissolution process. The additional last two questions in post-test 1 focused on the content modeling in the animations.

The pre-test was administered to understand the teachers' prior content knowledge; post-test 1 was to evaluate the teachers' content understanding after viewing first animations; and lastly post-test 2 measured teachers' content understanding one more time after viewing the last animation.

The researcher aimed to provide an opportunity for the participants to review their ideas and observations with the other participants' viewpoints by applying a group discussion in each group. The teachers discussed the last question of post-test 2 after completing the test individually. The purpose of the group discussion was to investigate teachers' prior opinions about using animations in their classroom to teach NaCl dissolving. Additionally, after the group discussion, the teachers answered the same question in a separate paper individually. By this mid-test, the researcher was able to compare the differences in the opinions of the teachers before and after they interacted to each other. Therefore, group discussion provided a communication opportunity to the teachers.

Reliability of pre-post measure. The researcher conducted a pilot study to validate the research assessments questions in order to understand if the questions targeted the understanding of the salt dissolution. The sub-group included four in-service science teachers studying for a master's degree in science education and attending a research class within their program. The researcher asked the pre-post questions to the sub-group in order to measure the quality of the answer. The researcher applied inter-rater reliability after scoring the pre-post tests responses based on the rubric. Pearson's Product Moment Correlation between the scores resulted in .83 for the pre-post tests. The r value suggested that the tests were appropriate to apply in this research. Lastly, a chemistry professor reviewed the test items and the rubric.

Animations

The researcher used four representative animations of salt dissolution in the study. All animations were chemistry content-based and open to public access. The researcher selected the animations based on the accurate representation of the content and functions of animations such as narration, and audial support.

Animation 1 included a daily life example in the content and molecular level of representation for both soluble and insoluble salts. A short one-minute demonstration also included audio explanation. The url of the animation website;
http://www.yteach.co.uk/page.php/resources/view_all?id=salt_acid_base_water_reaction_product_reactant_precipitation_thermal_decomposition_t_page_12&from=search

Animation 2 had written explanations and an audio option while displaying the representation. A one and half minute demonstration included symbolic modeling of molecules. Water molecules passed through the crystal to hydrate an ion in this animation. The url of the animation website;
http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/molvie1.swf

Animation 3 illustrated the concepts briefly, although it explains the phenomena in general. The animation included some inaccurate explanations. This two-minutes animation went step by step with the support of short text explaining the salt dissolution process. The url of the animation website;
http://programs.northlandcollege.edu/biology/Biology1111/animations/dissolve.html

Animation 4 had better illustration of the content compared to the other animations. Specifically, the illustration of the space between the water molecules in liquid state is less, which was more accurate compared to the other animations. The animation contained some inaccurate representations, illustration of the salt molecules and water molecules during the process of salt dissolution. The url of the animation website;
http://preparatorychemistry.com/NaCl_flash_audio.html

A critique of most public-domain animations is that they lack accurate consideration of the integration of content and pedagogy (Engida, 2014). With this in mind, the researcher selected the three public-domain animations to be used in this study. All four animations included the definition of solubility concept at the micro and macro-level representations; the animations also depicted the interactions and the nature of molecules and ions by the vibrating models proportionately. On the other hand, the animations were public and had some inaccurate representations as mentioned, which could also lead to some misconceptions.

Procedures

This study had a single focus; investigating teachers' understanding of the content from the animations they viewed. The sample of 10 in-service science teachers seated randomly in three groups. Group A consisted of four teachers; Group B consisted of three teachers, and Group C consisted of three teachers.

Table 1. The setting showing the phases of the implementation respectively

Group A	Group B	Group C
Pre-test for all group		
Animation 1	Animation 2	Animation 3
Post-test 1 for all groups		
Animation 4 for all groups		
Pre-test 2 for all groups		
Group discussion for all groups		
Question 7 for all groups		
Note: Group A includes 4, Group B includes 3, and Group C includes 3 teachers.		

Each group took the pre-test prior to viewing the animations. The purpose of this test was to assess the prior knowledge of the teachers' content of salt dissolution. After the testing, each group viewed different animations pertaining to the content: Group A viewed Animation 1, Group B viewed Animation 2, and Group C viewed Animation 3. The researcher repeated the animations in each group at the request of the participants. After the animation display, the teachers took the post-test-1. After the post-test 1, each group viewed a common animation, Animation 4 and then took the post-test 2. The last question of the post-test 2 was to write a paragraph regarding the ideas of the teachers about instructing salt dissolution. When the teachers answered the questions, the groups were given prompts to discuss about the content, application of the animations, features of the animations, and the strengths-weaknesses of the animations. After the group-discussion session, the researcher asked the teachers to write a paragraph about how they would teach the salt dissolution to analyze if the teachers changed their opinions before and after the group discussion. The entire testing and animation displays took two-hours in total. Table 1 illustrates the flow of the study.

DATA ANALYSIS

The researcher first analyzed the data descriptively. Powell (1996) explains "some common mathematical techniques that can make your evaluation data more understandable" in descriptive statistics (p. 1). The researcher used basic descriptive statistic method to analyze the data. The focus of this preliminary analysis was to understand and describe the influence of the treatment on the teachers' content knowledge.

The researcher analyzed the teachers' answers to each question separately. To analyze the first question, the researcher assigned certain colors and numbers to teachers' responses in order to quantify and evaluate the findings. Three colors (red, yellow, and green) referred to the accuracy level of the answers. Red indicated incomplete or inaccurate answers and the assigned number was "1." Yellow indicated any positive change, such as an improved explanation to the question on the post-test compared to the explanation on the pre-test and the assigned number was "2." Green showed accurate answers; however, the answers included some misconceptions, lack of inaccuracy, or incomplete explanations to a certain extent and the assigned level was "3." A participant's drawing evaluation is shown in Figure 1. All the other responses in the other questions were also quantified based on the levels in the rubric. The mean scores of the participants are presented for each question separately in the Results section. The researcher used *Microsoft Excel* to calculate the descriptive statistics by the scores of the teachers' assessments.

RESULTS

The findings are presented in three sections. First, questions 1-6 on the test are examined as they indicate a change in content knowledge. This is followed by the findings from Question 7 and the discussion.

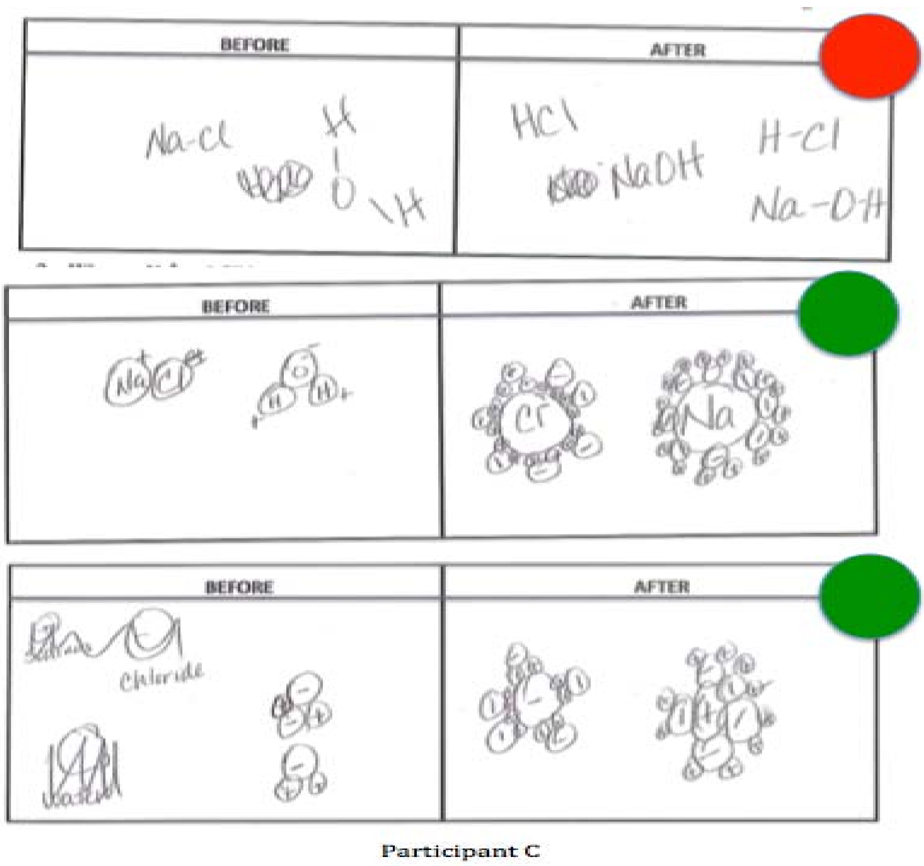


Figure 1. A participant's drawing of the process at molecular level for Question 1

Question 1: Drawings reveal the understanding of a phenomenon in a visual form is significant. The question asks teachers to draw an illustration about the salt dissolution of NaCl at molecular level before and after the dissolving process. The focus is on teachers' understanding of the content provided by the animations as analyzing the findings. The researcher compares the first drawings in the teachers' pre-test, post-test 1 and post-test 2 to detect the changes in teachers' understanding, and observes positive changes in general. Some teachers' drawings remain the same, but the findings do not inform about any negative change.

In Group A, four teachers' drawings exist for the first question. Two teachers remain the same in their drawings from pre-test to post-tests. One of these two teachers shows an improvement in post-test 1 compared to his drawing in pre-test, however; some serious mistakes put the participant in the same color level. The other teacher improved after viewing the second animation. One of the participant's drawings are shown in Figure 1. The order of the drawings is the order of pre-to posttest 1 to then posttest 2 applications: before viewing any animation, after viewing Animation 1, and after viewing Animation 4. The participant draws symbolic representation before viewing an animation, progresses by drawing molecular representation after viewing Animation 2, and keep the progress and draws the process similarly after viewing Animation 4.

Table 2. Each participant's mean scores for question 1

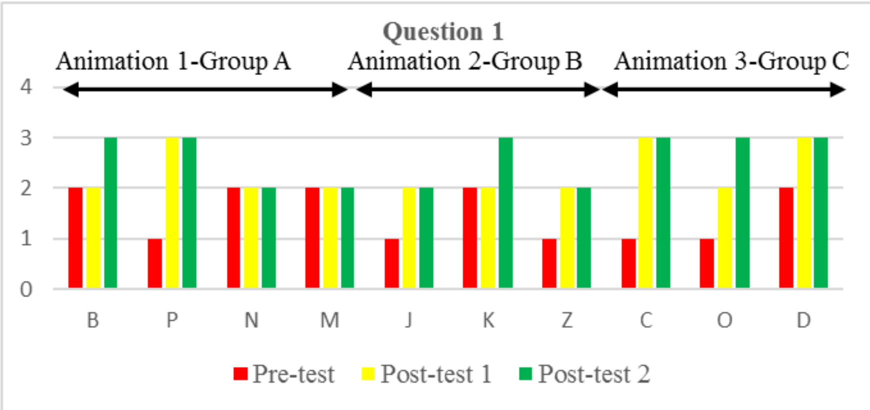
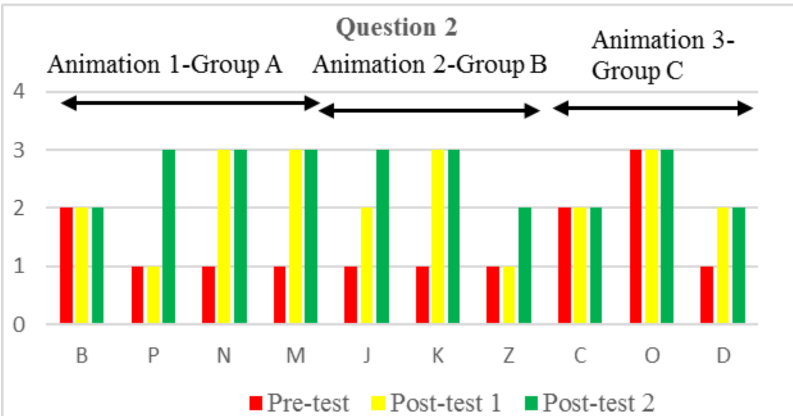


Table 2 shows the findings of the first question. The letters on x-axis represent the participants and each bar represents one of the test scores of the teachers (pre, post-1, post-2). First four letters represent the teachers in Group A, the next three letters are for Group B, and the last are for Group C. As shown in Table 2, three participants in Group B who viewed Animation 2 have positive changes in their drawings which means that most of Group B members improved in representing the process visually. Similarly, Group C also shows sharp improvements at molecular-level illustration of salt ionization in an aqueous solution. The teachers in Group C make a significant progress when they view the animations especially when watching Animation 1.

Table 3. Each participant's mean scores for question 2



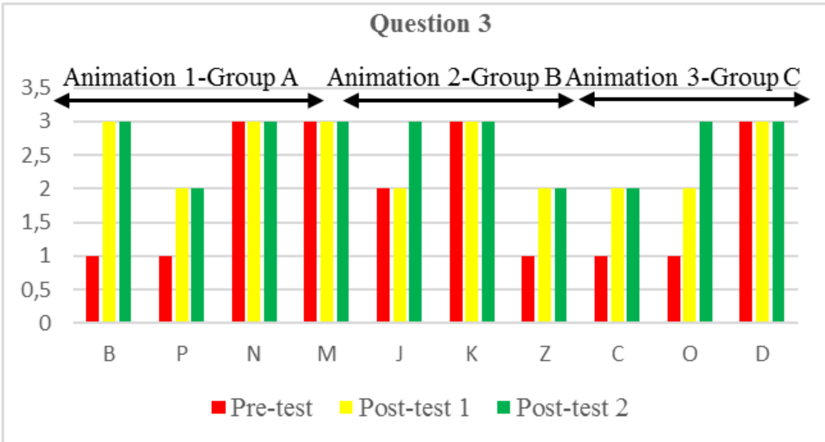
Question 2: The question asks why Na^+ and Cl^- ions disjoin from each other in solution. Salt dissolution occurs by the separation of Na^+ and Cl^- ions from the salt crystal. Partially positive sides of water molecules, which are hydrogen sides, attract the negatively charged chloride ion, and partially negative sides of water molecules, which are oxygen sides, attract the positively charged sodium ion.

With the second question of the tests, the researcher sought to understand whether the teachers are knowledgeable about the reason for the separation that is the fundamental part of the process. Table 3 shows the findings of the second question. People in Group A and Group B make strong progress after watching the animations; however, the teachers in Group C do not show similar findings but still improve in general after watching the animations. The average level of the groups ranges from 1.5 to 2.3 and then to 2.5. The range indicates a sharp increase in after the teacher viewed the first animation and some more progress after they view Animation 4. Even, the first representation of the process improved their understanding of the salt dissolution process at molecular level.

Question 3 asked if there was a significant interaction between the Na^+, Cl^- ions and water molecules. The aim of the question was to understand what the teachers thought about the strength between ions and water molecules interaction in an aqueous solution. Bonding and interactions occurred within and between the molecules such as covalent bonding. Though a strong nonpolar bonding, covalent bonding was relatively weak between molecules.

Instead Van der Waals played significant role in attaching the molecules and ions. Table 4 shows the findings of the third question. The average levels of Group 2 ranged from 1.9 to 2.5 and, then to 2.7, indicating a sharp increase after the teacher viewed the first animation and also showed some more progress after the second animation, which was very similar to the findings of the second question. Salt dissolution included dissociation and interaction of particles. Sodium chloride dissolved in water, and the sodium and chloride ions formed a lattice crystal when the formation of ionic bonds occurred. Water molecules surrounded the ions according to their charges. The water molecules pushed the Na^+ ions farther away from the solids, and the other water molecules moved between the escaping ion and the solid disrupting, the attraction to chloride ions still on the surface of the solid. The same steps led to chloride ions; water molecules pushed them farther away from the solids.

Table 4. Each participant's mean scores for question 3



The process went on until all the ionic bonds break and ion-water molecule interactions occurred, thus salt dissolution completed. However, teachers did not generally answer the fourth question in the way that the researcher intends. The question was about the molecular level steps of the process; however, the teachers answered the question as if the process consisted of the steps in preparation some salt solution in a laboratory experiment. To exemplify, the response in the rubric for question 4:

Q4: In a mixture of NaCl and water;
1. *Each water molecule collides with the NaCl solid.*
2. *Na+ and Cl- ions; the oxygen sides of water molecule push the Na+ ion farther away from the solid, and hydrogen sides of water molecule push the Cl- ion farther away from the solid.*
3. *Each Na+ ion is surrounded by six Cl- ions, and each Cl-ions is surrounded by six Na+ ions.*
4. *Other water molecules move between ions and the solid, disrupting the attractions to the solid.*
5. *The Na+ and Cl- ions, and water molecules move in the solution like any other particle in the liquid.*

However, one of the participants answered as, "Agitate the solution with a lab tool (spoon). Raise the temperature by placing it under a hot plate. Decrease concentration of NaCl and increase H_20; this way more H_2O molecules surround NaCl." Another teacher stated similarly, "Get a beaker, get a stir rod, fill the beaker with water, add the NaCl, stir with stir rod." The participants mostly answered this question similarly.
Question 5 asked the teachers to decide if the given statements in the question were correct or wrong. The first statement of the fifth question in the assessment (Appendix A) asks that ions were the same size as the atoms they came from, only to visualize that they were different ions. The answer should have been "false" since the ions' sizes were different than the size of atoms they came from. Five participants answered the statement correctly on pre-test. Three more teachers answered correctly after viewing the first animations, and eight out of ten teachers answered correctly at the end. The Na atom was smaller than the Na ion and the Cl atom was bigger than its ionic form. The second statement was, positive ions were smaller than the atoms they came from and negative ones are bigger. This statement directly connected to the first statement; however, the second one focused on the size of atoms and ions relative to each other. The right answer was "true" for this statement, and four teachers out of ten answered correctly to the statement on pre-test. One more teacher answered correctly after viewing the first animations, and six out of ten teachers answered correctly at the end. The phenomenon in the statement was apparent in all the presented animations and the image given in the question. The third

statement of the question asked if the modeling did not have any meaning, and if the ions/atoms were the same size. Chart 1 shows the overall findings for each participant.
Additionally, in the fifth question, Chart 1 showed the scoring of the teachers' responses. The researcher assigned random letters to the participants, shown in first column. In the chart, if the number of wrong answers to the statements was less tan two, the researcher painted the question yellow and assigned "2" to the yellow colored answers out of three. The researcher used green if the participant had no wrong answer to the statements. If two or more wrong statements occurred, the researcher colored the question red, and assigned "1" to the answers.

Chart 1. Teachers' scores in question 5

QUESTION 5		PRE-TEST	POST-TEST 1 ANIMATION 4	POST-TEST 2
GROUP A	-B-	2	2	2
	-P-	2	1	2
	-N-	3	3	3
	-M-	3	3	3
GROUP B	-J-	2	2	2
	-K-	3	3	3
	-Z-	1	1	1
GROUP C	-C-	3	3	3
	-O-	3	3	3
	-D-	1	2	1
AVERAGE		2.3	2.3	2.3

For example, Participants P made more wrong statements after the first animation but returned to the correct one after the teacher watched the second animation. Similarly, Participant D made fewer wrong statements after the teachers viewed the first animation, but made more again after the second animation. Three participants thought that the ions were the same size of the atoms they came from, and those participants did not change their answers even after the teachers watch the animations. One of the participants changed the answer to a correct statement, saying the positive ions were smaller than the atoms they came from and negative ones were bigger. Only one teacher answered the statement c, saying the modeling did not have any meaning and the molecules were the same size, which is wrong. Overall, the teachers did not change the answers to the statements and questions even after the animations. Lastly, all participants but one answered the last statement correctly.

Question 6 asked if the animations should have included any of the given ideas in order to improve the reflection of the reality. The sixth question appeared only in the first and the second post-tests since the question addressed the content of the animations rather than learning that occurred as a result of watching the animations. In other words, the aim of the sixth question was to investigate teachers' understanding of the mechanic features of the animations. For example, if the size of circles referring to the ions/atoms in the animations represented the accurate knowledge. The way that the animations demonstrated the phenomena differed in each. Coloring, size depiction, motion flow of the molecules, and the process itself, the spaces between the molecules and ions, interaction and bond illustration were some examples of differences. Determining if these aspects of the animations helped the learners to understand that the phenomena were important and if so which one(s) teachers used and reflected our understanding of reality. The suggestions followed: the angle between the atoms in molecules should be relative to the real angles; modeling of atoms and ions should be in equal spheres; spaces between molecules should be equal to each other, and bonding and intermolecular forces should exist in modeling.

First statement: The angle between the atoms in molecules should have been adjusted according to real angles. Wu, Krajcik, & Soloway (2001) state that the angles between the atoms in molecules need to be relative to the actual angles. Representing the actual angles in a modelling was possible by establishing a relativity between the angles of molecules in modeling. In this study, four teachers agreed with the given statement and the rest did not mark it as true.

Second statement: Coloring should be removed and all molecules should be in same color or colorless. The studies in the literature supported the idea of coloring the atoms in modelling in order to differentiate atoms.

Coloring or drawing different geometrical shapes were the methods to identify different atoms and separate them from each other in a modelling of a chemical phenomenon. Eight of the participants disagreed with the given statement since coloring helped to visualize the difference between the atoms.

Third statement: Atoms and ions should be modeled in equal spheres. The studies about modeling in science supported establishing a relativity with the reality in representations. Therefore, modeling Cl^- ion (higher electronegativity) in a smaller geometrical shape compared to Na^+ ion (lower electronegativity) illustrate the suggested representation. Eight participants out of ten state that atoms and ions should not have been modeled in equal spheres, since they were not the same size in reality, which aligns with the suggested representation.

Fourth statement: Spaces between molecules should be equal to each other. Considering the suggested idea of establishing relativity with the reality, spaces are better to be illustrated at different distribution since the space between the molecules are not equal even in homogenous solutions. Six teachers think that space between the molecules in a solution varies, but not constant, which aligns with the suggested idea.

Fifth statement: Bonding and intermolecular forces should be illustrated in modeling. In order to reflect reality in modeling, bonding and intermolecular forces can be illustrated. Eight teachers out of ten agree the idea of adding the illustrations of bonding and intermolecular forces in to the modeling. Two of them think that this addition make the illustrations look too busy; not a good idea to add these forces into the modeling.

Group Discussion

The last question, which appeared only in the post-test 2 sought to determine teachers' prior ideas about their instructional teaching of NaCl dissolution. After the second post-test, the researcher asked the participants to discuss the role of the animations in teaching, and also the aspects and the content presentations of the animations. Teachers kept the groups that they formed in this study, Group A, B, and C, and the discussion took place between the group members. The aim of the group discussion was to measure the difference of the teachers' ideas on the strategy that they would apply for teaching the topic in their classrooms.

Participants in Group A did not change their opinions after the discussion session; two of them determined to use animations in their instruction before and after the group discussion. One of the participants chose not to apply animations since he disagreed the idea that animations improved students' learning of the content. The other participant referred to the use of multimedia application in his classrooms but not specifically animations even after the group discussion. Two participants in Group B changed their minds and decided to use animations in their classrooms and the third participant kept thinking about applying animations. Only one participant in Group C did not consider applying the animations in the classroom, and after the discussion, the participant changed her mind and stated that she applied animations while teaching salt dissolution topic to the students.

DISCUSSION

The first six questions gave insight into the value of animations for helping students develop conceptual understanding. The discussion provided more information about teachers' opinion about using animations in the classrooms.

Visual Aspects of Animations Help

First Question: Studies reveal that different representations have distinctive attributes that both guide and constrain what learners do and come to understand (Ainsworth, 2006; Scaife, & Rogers, 1992; Tversky, 2011). Considering this indication, the researcher asked the first question to measure the difference between drawings before and after watching each animation. Group A watched the shortest animation; the molecular representations were not as large as the ones in the other animations. The disadvantages of the Animation 1 could account for the slight improvement of Group A comparing to the improvement in the other groups. For example, Teacher M in Group A drew the salt in two dimensions, but changed the model to three-dimensional shapes after watching Animation 4. The teacher kept drawing inaccurate demonstrations after viewing Animation 1 but fixed after viewing Animation 4. Therefore, Animation 1 did not help to fix the inaccurate understanding whereas Animation 4 helped to improve teachers' understanding about the accurate and consistent molecular demonstration. On the other hand, the progress that teachers in Group B and C showed the quality of the animations compared to Animation 1. Animation 2 and 3 demonstrated the molecular-level demonstration in a slow pace so that the participants had time to view the process in detail. In conclusion, Animation 4 supported the improvement the most because it included the most accurate demonstration, teachers' understanding strengthened after viewing Animation 4. In addition, the length in Animation 2 and 3 increased the time required for teachers' understanding of the process. For example, in Group B, Teacher Z drew the salt crystal as separate NaCl molecules, and changed the modelling in her drawing to the modelling of the animations. The participant separated the molecules rather than depicting them as clusters, which was also visualized in the animations so that the teacher adopted the demonstration into her drawing. In general, the improvement in drawings implied that the molecular representations of the animations influenced the participants' drawings significantly. The important deduction from the drawings is that Animation 2, 3, and 4 without further instruction improved teachers' understanding of salt dissolution process in general at molecular-level in this study.

Second Question: The researcher used rubric to score teachers' responses. In the second question, teachers' understanding of content increased after the they watched the first animations. Question 2 asked the participants to explain why Na^+ and Cl^- ions disjoint from the salt crystal. All animations presented the molecular-level modelling of ions and molecules and demonstrated the changes during the dissolution process accurately. Since the animations represented the separation of the ion from the salt crystal through dynamic representations successfully, teachers showed progress in answering to the question without any further instruction. Separation of the ions is the core part of the phenomenon and having a clear understanding of this part requires visual adjunct such as animations. For this question, regardless of the aspects of animations (time length, quality of visual representation, narrative or audial support, etc.…) teachers improved even after viewing the first animations. The finding addresses the need for visual representations in teachers' understanding of the content at molecular level.

The first two questions of the test were different than each other in terms of assessment type; the first one was a drawing and the second one was written-based question. The answers to these questions in each group improved regardless of the way teachers expressed their knowledge. Therefore, this improvement refers to the influence of the explanations and representations of the animations that the teachers viewed.

Content Understanding from the Animations with Certain Aspects Differs

Third Question: In this question, specifically the teachers in Group B did not show as much improvement as the teachers in Group A. Animation 1 (Group A) included a molecular-level example to soluble salt. This daily-life example helped teachers understand the concept in a way that those teachers overpassed the teachers in the other groups. As many researchers state, the existence of daily life example in an instruction or demonstration is important in content understanding. With the insoluble salt example, Animation 1 presented the interaction between the ion and the water molecules. It also provided an opportunity to visualize and compare on how an interaction could take place between the molecules. On the other hand, Animation 2 (Group B) included only the interaction in the demonstration, but not emphasized the interaction by presenting insoluble salt which was a compare-contrast example for the teachers. Therefore, teachers who viewed Animation 1 benefitted of the animation more than the teachers who viewed Animation 2 because of the difference in the quality of content presentation of the animations. Similarly, Group C improved more after watching Animation 3. However, interestingly, Animation 3 did not include the reasoning for an insoluble salt. Therefore, these two teachers had the understanding about the interaction between the ion and the water molecules prior to view the animation. Nevertheless, the visuals showing the process between the molecules could have been explanatory for the teachers in visualization of the interaction between the ions and the water molecules. In summary, the first animations helped teachers understand the salt dissolution process better based on their different features of representations. In general, including daily life example, presenting reasons of the phenomena, and visual representation aspects help teacher understand the process better.

Fourth Question: Most of the participants did not answer the fourth question in the way the researcher intended with this question. Emphasis on molecular-level descriptions in explaining the salt dissolving process was missing in the question. All the animations except Animation 4 explained the the description of the process in the order. Animation 1, 2, & 3 demonstrated the macroscopic view of the process before salt and water interacted at the beginning. Next, the animations showed how they interacted and which atom attracted which ion in detail. Among these three animations, only Animation 1 was comparatively speedy so that viewers could have missed the attraction between the atoms and ions. However, the order in the interaction was clear in all except Animation 4. Animation 4 was the common animation and missed the macroscopic view of the process. Therefore, the participants could have been confused about the order of the process because of the missing macroscopic level demonstration as well as the crowded nature of the animation.

Teachers' Preferences and Perceptions about Visual Representation of Dissolving Differ

Fifth Question: Studies in the literature suggest to apply relative reality in representations, which implies not to include coloring in the model molecules. In the context of this study, coloring in the animation was only to depict different atoms, and identify different atoms in representations. If the models were in the same color, confusion could occur. The emphasis on the fact that coloring is only to model and differentiate atoms in the animations but does not exist in reality might help students to understand the animation in reality.

In this study, one of the eight participants agreed to include coloring in animations and stated, “Even though the colors are not real they make the animation easier to understand.” Another participant stated, “Coloring can help to see the process better, so keep it colored.” Teachers were mostly aware of the fact that in reality coloring did not exist. All the animations that the teachers watched was colorful; therefore, a comparison between the ideas of the teachers depending on the animations they watched is not a pic for discussion. The next statement was, “modeling of the atoms and ions should be in equal spheres.” Ions and atoms are not the same size in reality, so not equal to each other. Modeling the molecules in equal spheres might lead to the understanding that all atoms and ions are equal spheres. One of the eight participants who agreed with illustrating the atoms and ions in different sizes stated, “the difference in shapes and sizes help with identification.” Teachers also were aware of the difference between the sizes of ions and atoms, and supported to illustrate them in different sizes in the representations. Additionally, all the animations depicted the relative size of the molecules accurately.

Furthermore, the drawing question (first question) in the tests, was also related to the modelling in the fifth question. The answers to the modelling statement was associated to the drawings of the participants. When compared drawings to the teachers’ statements about the size of the atoms, an interesting point was revealed. The first two statements in the fifth question was about the size of the atoms and regarding the charge of the ions. “Positive ions are smaller than the atoms they come from and negative ones are bigger” was the statement related to size of the molecules.

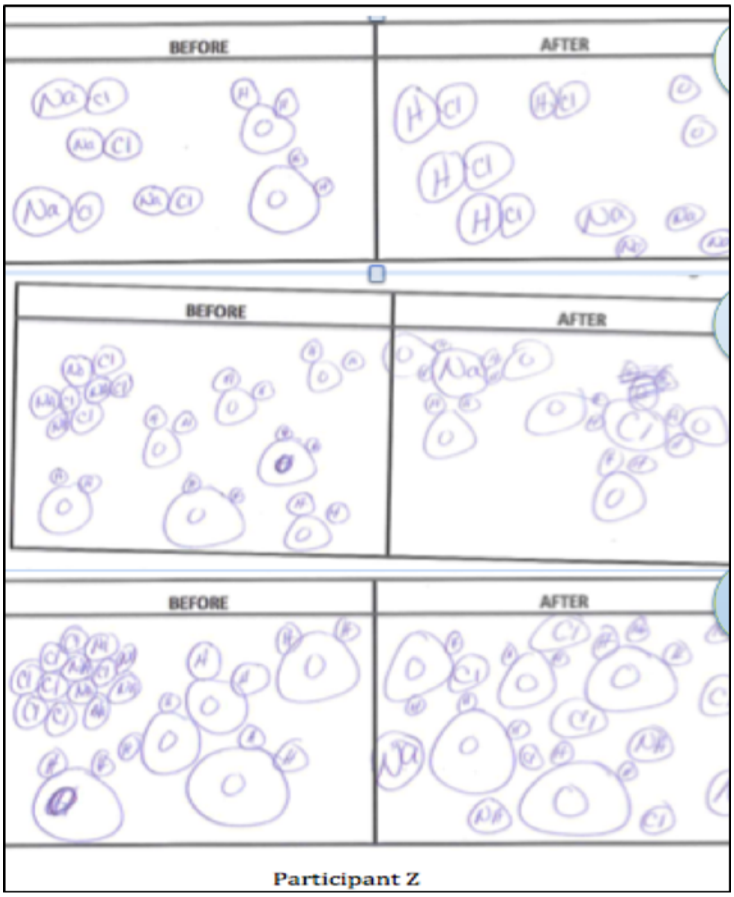


Figure 2. Drawing of Participant Z

Participants who agreed with this statement were expected to apply the written statement in their drawings. Therefore, the participants were expected to draw a bigger model for Na atom in the salt crystal but relatively smaller in the aqueous solution. However, they did not. According to the findings of the study, none of the participants paid attention to their drawings in terms of the size of the model molecules before and after viewing the animations. Figure 2 shows the drawings of a participant. The inconsistency between the content of the drawing and the statement of a participant was apparent in the drawings. The majority of the drawings of the participants were similar on this inconsistency.

The sixth question was also related to animations’ illustrations of the content, specifically demonstration of the angle within the water molecule, space between the molecules and ions, geometrical shapes of the molecules and ions, and the bonding representations. Therefore, drawings of the teachers could be compared to their statement to check whether they understood and applied the content or the understanding was in-surface.

The spaces between the molecules were not exactly equal for each molecule even if the solution is homogeneous. Therefore, these two teachers could have misconceptions about the process at molecular-level. Animation 3 was incomplete in representing the macro-level perspective of the phenomenon; it also lacked accurate representation about the spaces between the molecules before and after the salt dissolution process. This misrepresentation could account for the inaccuracy in the statements of the teachers in Group C. Animation 1 demonstrated the happenings before and after the salt dissolution process accurately in terms of the space between the molecules. Therefore, the teachers in Group A had opportunity to compare the spaces in both soluble and insoluble salt and water mixtures. When compared their drawings into their statements, all teachers even Group C drew unequal spaces between the molecules with or without purpose. Two participants in Group C did not support to have colors in animations. To explain the difference between a colored and non-colored animation, it would be good to have an animation with no color.

In that way, teachers would also have an opportunity to compare them. However, the animations were all colored. Even though this was the case, all the other teachers supported to have colors to differentiate the atoms from each other.

The last statement suggested to include the representations of bonding and intermolecular forces in to the animations. In fact, to see the bonding and all the intermolecular forces between the molecules and ions in the animations is helpful; however, the animations represent the phenomena in many ways, such as relative sizes of atoms and ions, motion of the particles, different identity of them and chemical bonding within the compounds. If the other interactions like intermolecular forces were to be included, the animations would become more complex and harder to concentrate the happenings. Illustrating intermolecular forces would help students to see attractions between the molecules comprehensively, in order to demonstrate the salt dissolution phenomena clearly, animations were better to exclude bonding and intermolecular forces. However, eight of the ten teachers disregarded the idea of inclusion of the bonding and intermolecular forces to congest the modeling. Two teachers supported to include the intermolecular forces but interestingly exclude any representation of intermolecular forces or bonding in their drawings.

To summarize, the findings in this preliminary study indicated that animations providing accurate demonstration about molecular representations as well as providing enough time for the audience to understand the happenings in demonstrations supported teachers' content understanding consistently. In addition, daily-life example presentation strengthened content knowledge of the teachers. Lastly, the features of the animations such as coloring and slow pace, the angle and size representation of the atoms and molecules were different but teachers were mostly aware of the accepted ideas in chemistry.

Teachers Like Animations

The open-ended nature of the of the written response to question 7 and the discussion that followed provide additional insight into the value of using animations for helping teachers develop conceptual understanding. Question 7 followed the demonstration of the animations; which teachers would or would not prefer to apply in their own classroom. The open-ended nature of the question helped the researcher understand whether the teachers liked the animations and thought that the animations were useful or not. Most of the teachers thought that they would apply the animations in their classroom as instructional tools, which suggested that they benefited of the animations so that they liked their students to benefit of them. The improvement in the mean difference between the pre-post tests also verified the idea that the teachers benefitted of the animations in terms of content learning. Therefore, teachers were ready to use animations in their classroom if they were given the resources. Professional workshops might focus on the effective use of animations and provide different resources about the animations in different subject matters.

Group discussion opportunity was presented as an option to clarify their understanding of using animations or the content presented by animations. Observing the teachers trying to reason their viewpoints about why animations could help students' understanding was one of the expected benefit of the discussion. Their reasoning about applying animations were directly associated with the modelling features of animations and the animations' possible influence on students' content knowledge. The teachers in this preliminary study supported using animation in classrooms because of its graphical aspect other than the content presentation. Teachers did not only improve by the help of animations but also attempted to convince each other that the animations would help their students' content understanding.

This repetition also supported that teachers found the group discussion as a chance to reason and explain why and how they benefited of the animations as well.

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APPENDIX

Pre-Post Test

(Pre-test includes only questions 1,2,3, and 4; Question 5 & 6 are only in Post-Test 2; Question 7 is the instructional strategy question)

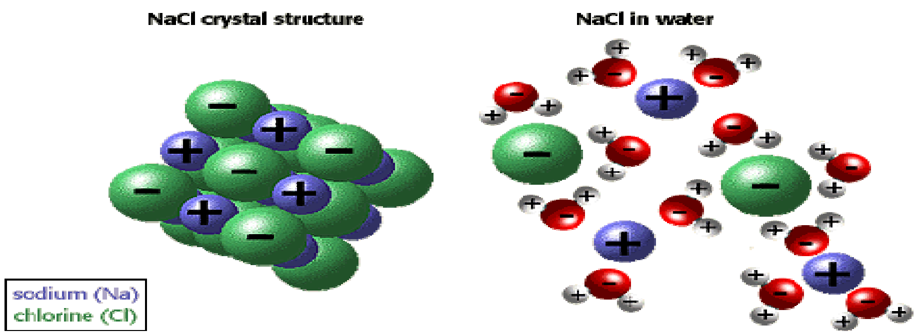
1- Please draw the NaCl and water molecules in molecular level before and after dissolving.

BEFORE	AFTER

2- Why are Na^+ and Cl^- ions separated from each other in solution?

3- Is there a significant interaction between the Na^+, Cl^- ions and water molecules? Explain.

4- List 5 important steps in dissolving NaCl in water. Please write one sentence per step.



5- Based on the image above, which of the following(s) are correct statements?

a) Ions are the same size as the atoms they come from but it is only to visualize that they are different ions.
b) Positive ions are smaller than the atoms they come from and negative ones are bigger.
c) The modeling does not have any meaning. They are the same size.
d) Liquid water is correctly portrayed

6- Which one(s) of the following ideas should be applied to the animation in order to improve the reflection of the reality? Please write one sentence per item.

- The angle between the atoms in molecules should be adjusted according to real angles.
-
- Coloring should be removed and all molecules should be in same color or colorless.
-
- Atoms and ions should be modeled in equal spheres.
-
- Spaces between molecules should be equal to each other.
-
- Bonding and intermolecular forces should be illustrated in modeling.
-

7- Please write a paragraph on what would be your instruction approach in teaching NaCl dissolving?
