Teacher Professional Development Using Iterative Inquiry-Based Chemistry Workshop

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TEACHER PROFESSIONAL DEVELOPMENT USING

ITERATIVE INQUIRY-BASED

CHEMISTRY WORKSHOP

by

Clint Eaton

B.S. East Carolina University 1999

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TEACHER PROFESSIONAL DEVELOPMENT USING

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CHEMISTRY WORKSHOP

By: Clint Eaton

Thesis Advisor: Dr. Mitchell R. M. Bruce

An Abstract of the Thesis Presented in
Partial Fulfillment of the Requirements for the
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The National Science Teachers Association recommends that all science teachers use instructional practices that support scientific inquiry, in alignment with Next Generation Science Standards that integrate content with inquiry practices. However, research has shown that many science teachers do not have robust understandings and experiences of scientific inquiry or may not manifest it successfully in their classroom practices. This study investigates teachers’ learning of inquiry elements including scientific communication skills and evidence and reasoning to support claims, through the use of iterative inquiry-based chemistry activities. The study was conducted during Professional Development (PD) in the context of a rural Mathematics and Science Partnership (MSP). We asked three major questions related to the effects of iterating inquiry activities:
1. What was the effect of the professional development on teacher’s scientific communication skills?

2. In what ways did the professional development affect the use of evidence and reasoning in supporting claims?

3. What was the effect of the professional development on teacher’s understanding of inquiry?

Our research questions are chosen to evaluate the impact of a designed professional development experience embedding components of effective PD and our iterative model. The workshop offered a variety of activities that were focused on content information and discussions of teacher’s gaps in understanding. The PD participants conducted activities including inquiry-based laboratories, content presentations, chemistry theory, clicker questions, discussions, and demonstrations. The iterative inquiry chemistry workshop model included an iterative design offered to the cohort. The five steps of the iterative activity were inquiry, data collection, data analysis, poster creation, and community discussion. The iterative experience was initiated with guided inquiry and then moved to more open inquiry. At the end of each inquiry iteration, groups of teachers constructed posters. The posters scientifically communicated their experimental findings and were used as a data source for this study.

The data sources included pre and post surveys, posters that were constructed at the end after each iteration of the activity, and interviews with teachers (1 month and 18 months) following completion of the workshop. Data collected during the workshop was used to evaluate our claims regarding the workshop’s effectiveness.
The data sources were analyzed both quantitatively and qualitatively to evaluate our research questions. Pre and post surveys provided insight into teacher’s scientific understanding as well as qualitative data used to assess the workshop’s impact. The posters created at the conclusion of each laboratory explicitly communicate the teacher’s scientific findings and were analyzed with a rubric that was designed to measure participant’s communication of informational elements, data, and conclusive findings. The short and long term teacher interviews illuminated the impact on teacher’s instruction, as it pertains to strategies and techniques learned during the iterative inquiry chemistry workshop.

The qualitative and quantitative data collected were assessed for commonalities to provide evidence in support of three claims. The first claim was workshop participants increased their understandings of the practice of scientific communication and gained practical skills in scientific communication. The second claim was teachers’ understandings of using evidence and reasoning to support claims improved during the iterative workshop. The third claim was the iterative nature of the iterative inquiry chemistry workshop facilitated an increase in teacher’s understanding of scientific inquiry.
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CHAPTER 1
INTRODUCING ITERATIVE, INQUIRY-BASED CHEMISTRY ACTIVITIES FOR PROFESSIONAL DEVELOPMENT OF K-12 TEACHERS: OUR MOTIVATION AND QUESTIONS

The National Science Teachers Association recommends that all science teachers use instructional practices that support scientific inquiry, in alignment with Next Generation Science Standards that integrate content with inquiry practices (NGSS, 2013). However, research has shown that many science teachers have limited understanding and experience with scientific inquiry (Capps & Crawford, 2013). This is consistent with the idea that inquiry is not well integrated into many science teachers’ classroom practices (Bartos & Lederman, 2014; DiBiase & McDonald, 2015). Also, while inquiry can be defined in many different ways, including using the scientific practices described in NGSS, the type of inquiry we suggest teachers often lack involves investigations that include developing their own procedures (Bruck, 2009). In addition, teachers do not have opportunities to communicate analysis and results conducted in an atmosphere of lively peer interactions, where the strengths and weaknesses of particular scientific investigations can become evident. We posit that this limited understanding and experience with scientific inquiry can make it difficult for teachers to facilitate inquiry in their own classrooms.

Current models of professional development which are typically single inquiry experiences may not be effective, leading to limited growth of teacher’s pedagogical skills (Capps, 2012). Scientists often learn by experiencing a series of related inquiries, where concepts and insight are iterated from one experience to the next. These iterative processes, which include building skill in thinking about a problem, developing insight, and communicating with other
scientists, appear to be absent in the present PD models. Specifically, the typical professional development offered (e.g. workshops) does not include iterative experiences that allow participants to gain experience with asking questions, designing experiments, offering explanations, challenging others’ work, and communicating scientific results. We were therefore interested in designing these aspects into a multi-day iterative inquiry chemistry workshop for middle and high school teachers offered at the Summer Academy 2014 as part of an interdisciplinary NSF MSP project (NSF MSP: 0962805 DRL Maine Physical Sciences Partnership (Maine PSP): Research and Infrastructure for Ongoing Educational Improvement).

The Summer Academy 2014 included about 100 K-12 teachers, with content PD workshops in areas such as chemistry and physics. The 2014 Chemistry Summer Academy strand included ten middle and high school teachers from rural schools participating in the MSP. Many of these teachers had either taught using the MSP-selected curricular materials for Chemistry (the first two modules of SEPUP Issues and Physical Science) in the previous year or were preparing to teach it in the coming school year. Half of the teachers were male, half were female, and all were Caucasian. The teachers were diverse in their teaching experience, ranging from one to over twenty years. Participants had self-selected for the workshop, having been given a choice of two strands of Physical Sciences PD. During the PD preparation, careful attention is required to integrate critical elements needed to achieve our goal. The elements are scientific communication, apprentice model, peer learning, scaffolded learning, and group dynamic described in further detail in the following paragraphs.

The study conducted during and after the workshop investigated teachers’ learning practices including scientific communication, evidence and reasoning to support claims, and inquiry. Scientific communication was a focus of the workshop because sharing findings within
the scientific community is a crucial part in the development and refinement of scientific ideas. (APA, 2001; Halonen, 2003)

The practice of scientific communication offers opportunity for engagement with a cohort of fellow teachers undergoing content instruction, inquiry-based activities and analysis that focus on scientific process. These elements form the basis for discussion and interactions during the iterative inquiry chemistry workshop and deepen teacher’s appreciation of what students go through in learning. The deepening of chemical knowledge is usually transferred through an apprentice model, where the apprentice models the thinking process of the scientist (Hodson, 1993).

Peer model of learning has been a strategy utilized in mastery of trades as well as education and it’s applicable in numerous venues including science (Boud, 2001). Peer learning is a mutually beneficial endeavor that benefits both parties involved. The individual discussing and explaining learns a great deal by communicating their ideas and the individual who listens also learns.

The iterative inquiry chemistry workshop activities were conducted as activities that required peers to communicate and learn from each other with a common goal of completing the activity. Each activity required groups of 3-5 teachers to produce a poster which was presented and discussed. Little instruction was offered about how to create the poster other than to present findings, analysis, and any claims they could make. Through these discussions the individuals become more confident in their communication abilities.

Part of the design of the iterative inquiry chemistry workshop was to give teachers a scaffolded training experiment. Leadership skills and group dynamics can be scaffolded (Harper, 2015) through training experiences. Undergraduate students, who are members of a peer led
group, receive leadership training as members of a group. Faculty often find it advantageous to
develop student leaders for subsequent peer led group discussions. As peer facilitators these
students exhibit skills obtained during both their practice as leaders as well as during their role as
a group member. This can significantly improve the learning environment in classrooms.
Accordingly, teachers who experience a similar experience, can develop facilitation skills, which
they can bring back into their classrooms to help their students examine the scientific process as
part of classroom discussions.

The group dynamic interplay is naturally interwoven in the iterative nature of the poster
sessions. As stated in Yezierski, teacher’s inquiry understanding is impacted through “support
features including reflection, cohort membership, and teacher-faculty collaboration. (Yezierski,
2011)” The cohort reflects upon the poster creation process through a collaborative discussion.
The poster session provides an opportunity for communication growth as the comparison of
posters illuminates obvious deficiencies between each group. This opportunity requires groups to
constructively critique their poster as well as other groups. Similar to the peer learning, as the
cycle is repeated, groups will learn from one another during the scientific communication portion
of the cycle.

**Statement of Research Questions**

To examine the effectiveness of the teacher PD in the 2014 Iterative Inquiry Chemistry
Workshop, we asked three major questions related to the effects of iterating inquiry activities:

1. What was the effect of the professional development on teacher’s scientific
   communication skills?

2. In what ways did the professional development affect the use of evidence and
   reasoning in supporting claims?
3. What was the effect of the professional development on teacher’s understanding of inquiry?

Our hypothesis was that inquiry iteration will lead to increases in teacher scientific communication skills, in use of evidence and reasoning in support of claims, a deeper understanding of inquiry, and thus greater degree of preparedness in teachers. The design of our workshop was predicated on creating activities that would allow teachers to develop skill in communication, use of evidence and reasoning, and understanding how iterating inquiry can lead to refinement and a higher quality of investigating a scientific question.

**Overarching Goal of Iterative Inquiry Chemistry Workshop**

Science education has been under the microscope, as the educational community explores strategies to improve instruction and increase students’ competitiveness in the ever-changing global workplace as well as result in better-informed citizens that will bolster decision-making within society (NRC, 2000). The influence of teachers on student performance and development is instrumental and therefore in the educational community’s spotlight.

As teachers are concerned with education and learning, they are expected to remain current in their field and typically receive professional development within their K-12 community. Professional development, the training that faculty receive to become more effective in educating students, consists of a variety of strategies including classroom management, inquiry based laboratories, flipped classroom and book studies. The professional development community is rich with veteran “experienced educators” as well as rookies “lacking in experience”. The veteran educators have mastered nuances within their craft and they serve as role models for the rookies.
Teacher’s influence on education and society is of the utmost importance and is the focal point of policy and research (Prawat, 1992). Teachers receive their undergraduate training at Universities and are then employed by school systems. Throughout an educator’s thirty-year teaching career, skills and strategies learned in the classroom must be practiced and tuned. The professional development instructors receive during their career is instrumental in polishing their craft and informing educators on new, exciting, educational strategies that can be implemented in the classroom. Well-planned and carefully developed professional development opportunities can be rich and fulfilling to instructors (Yezierski, 2011).
CHAPTER 2

LITERATURE REVIEW OF VARIOUS MODELS OF PROFESSIONAL DEVELOPMENT

Capps’ conducted a critical review of the models of professional development for their effectiveness (Capps, 2012). Capps’ critique analyzes professional development experiences for effective critical factors. Capps states “Unless teachers are supported in developing an understanding of science subject matter, the nature of scientific inquiry, and how to create an inquiry-based learning environment in the classroom it is unlikely there will be a significant shift in teacher’s practices. Analysis of Capps’ studies reveals three factors, enumerated below, that are critical to take into account when designing professional development for inquiry-based instruction (Capps, 2012). The factors are:

1. Understanding of science subject matter (science content)
2. Learning about the nature of science (NOS)
3. Experiencing an inquiry based learning environment

Because iteration of the scientific method is usually needed in investigations, we are also including a fourth factor here, which is:

4. Iterating inquiry (multiple opportunities to engage in inquiry experiments)

Although this fourth factor is absent in any of the PD models reviewed by Capps (see Table 1), our working hypothesis was that if present, it would lead to a deepening of understanding of the other three factors. We discussed this iterative PD approach in chapter 3. In Table 1, we have gathered examples of the PD studies reviewed by Capps and analyzed them for the presence of
primary (P) or secondary (S) research foci in the four factors listed above: science content, nature of science, experiencing inquiry, and iterating inquiry.

Table 1. Research author and the research’s categorical factors encompassing Science Content, Learning about NOS, Experiencing Inquiry, and if an integral part of the PD model includes Iterating Inquiry. P indicates that the PD model has a primary emphasis on this factor, S indicates that it has a secondary emphasis, while – indicates that it is missing.

<table>
<thead>
<tr>
<th>Author</th>
<th>Science Content</th>
<th>Learning about NOS</th>
<th>Experiencing Inquiry</th>
<th>Iterating Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loucks-Horsley et. al. (2003)</td>
<td>P</td>
<td>-</td>
<td>P</td>
<td>-</td>
</tr>
<tr>
<td>Herrington (2014)</td>
<td>P</td>
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<td>-</td>
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<tr>
<td>Jean-Pierre (2005)</td>
<td>S</td>
<td>S</td>
<td>P</td>
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</tr>
<tr>
<td>Blanchard (2009)</td>
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<td>S</td>
<td>P</td>
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<tr>
<td>Bartos (2014)</td>
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<td>S</td>
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<tr>
<td>Bruck (2008)</td>
<td>-</td>
<td>-</td>
<td>P</td>
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<td>Fay (2007)</td>
<td>-</td>
<td>-</td>
<td>P</td>
<td>-</td>
</tr>
<tr>
<td>Minner, Levy, and Century’s (2010)</td>
<td>S</td>
<td>-</td>
<td>P</td>
<td>-</td>
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<tr>
<td>Severs (2013)</td>
<td>-</td>
<td>-</td>
<td>P</td>
<td>-</td>
</tr>
</tbody>
</table>

Science content is the understanding of concepts and factual evidence within science fields, in other words science knowledge (Herrington, 2014). Nature of science is a creative, fluid scientific method used by students to expand and construct their scientific knowledge (Jean-Pierre 2005). Inquiry is student’s opportunity to explore solutions, problems, and construct explanations, and is an essential part of the nature of science (for our research we have deconstructed inquiry into separate factors) (Loucks-Horsley et. al. 2003). Iterating inquiry are multiple opportunities to engage in inquiry experiments that creates deeper understanding of inquiry. Iterating inquiry is essential to scientific process and to the best of our knowledge, is not typically included in professional development.
As Capps characterizes it, unless the first three categories listed in Table 1 are addressed, there will not be a significant shift in teacher’s practices, with the goal being to prepare a teacher to understand science, engage students, and facilitate student learning in science classrooms. Given the importance of these categories in the PD Models (see Table 1), it seems instructive to review and analyze each of these as separate factors in order to understand their contributions towards effective professional development. We have added iteration as a factor to Table 1, because this is a generally accepted process of deepening understanding of a research area.

**The Factor Science Content**

In this section we describe the 2 PDs for which this is a primary element. The Loucks-Horsley et. al. professional development model includes multiple elements. Science content knowledge and pedagogical skills are important aspects of the PD model. Loucks-Horsley connects the importance of teacher content knowledge and student learning. Teacher content knowledge is a key ingredient in effective instruction. Content focus during a PD opportunity can positively impact teacher’s content knowledge and can have ramifications in the classroom. Additional emphasis is placed on inquiry-based learning, investigations, and problem solving where students experience inquiry, and models teaching strategies during the professional development that teachers will use with their students. Purposeful design is required to integrate these complex entities together to achieve an effective professional development model. Gains in instructor science content knowledge are the primary focus of the Loucks-Horsley PD model. We note that although PD involving science content can be iterated, this is an element that is not directly addressed in the Loucks-Horsley PD model.
The Herrington PD model focuses on deep conceptual understanding of content knowledge. The deepening of conceptual understanding is instrumental in effective professional development. Herrington proposes moving away from typical algorithmic problem solving strategies used in worksheets and structured lab activities in the classroom and towards deeper conceptual understanding (Herrington, 2014). In Capps review multiple literature articles highlight the importance of science content knowledge (Capps, 2012). Multiple research literature articles that describe the resulting student-learning gains from increasing teacher’s content knowledge are well documented (Driel, 1998). We note that although the Herrington PD involves research that presumably would include iteration of science, communication on a daily basis may be of an informal nature, with a report out at the end of the research experience (e.g. poster, oral presentation, paper). The iteration factor that we include in Table 1 that we suggest is absent in this model is a more complete iterative process that would involve analysis, presentation of results, discussion with participants that would be iterated after each inquiry experience.

The Factor Nature of Science (NOS)

Bartos’s contribution to professional development is understanding knowledge of nature of science and its translation into student’s views. The Bartos literature article summarizes that instructor knowledge of nature of science doesn’t necessarily translate in the classroom to students and provides an opportunity to improve current nature of science understanding (Bartos, 2014). Knowledge of nature of science and facilitating discussion that focus on understanding of science is an explicitly stated goal for this professional development. Bartos states the positive impact of nature of science understanding on the learner, i.e. considerable student-learning gains are a result of receiving instruction through inquiry.
Research conducted by JeanPierre depicts a teacher’s experiences as vital to the effectiveness of the professional development. The teacher’s experiences included numerous opportunities to engage in short laboratories, presentations, and deep science content understanding (JeanPierre, 2005).

JeanPierre’s professional development model includes opportunities to engage in science practices. The process is designed to create an environment to develop research based skills. Additionally, content is an important aspect of JeanPierre’s work. Selectively chosen high level content knowledge is integral during the experience. Integration of nature of science knowledge and the content is a vital component of the PD model. A key point alluded to in the JeanPierre article is that teachers learn like students and must experience the learning opportunity in order to gain expertise. Additionally, collegial support is available for nature of science and pedagogical questions, during the professional development, as well as throughout the year.

Research conducted by Blanchard describes a professional development opportunity. The PD is a research opportunity for teachers that are similar to their student’s experience (Blanchard, 2009). Qualitative and quantitative data are obtained on teachers’ pre and post nature of science conceptions. The work by Blanchard stresses the importance of a teacher’s understanding of the nature of science and inquiry. Blanchard’s assumption is that the teacher’s research experience will facilitate conceptual change and beliefs of nature of science. A conceptual change is suggested that requires teachers to reorganize their views and understanding of the world around them. This is accomplished through reflective practices both in writing and through discussions, where teachers wrestle with understanding “why” and “what” they are doing. Interpreting the impending change in a teacher’s belief and understanding is also
a vital part of the professional development model. Specifically, changes in the complexity of classroom questions are a focal point of the analysis, and how they evolve after instruction.

**The Factor Experiencing Inquiry**

Experiencing inquiry is an essential part of effective models of professional development. Through experiencing inquiry a better understanding of inquiry occurs (Blanchard, 2009). A measurement technique is created by Bruck to measure the level of inquiry for undergraduate laboratories. Bruck created categories of inquiry ranging from level 0 (Confirmation) to level 3 (Authentic Inquiry) to measure the differing amounts of inquiry (Bruck, 2008). Bruck displays a rubric that can be used to measure the level of inquiry in the laboratory. In our professional development, teachers engage in multiple types of inquiry including open inquiry that integrates chemistry activities. Bruck defines open inquiry (Level 2) as the learner creating the procedure, results, communication and conclusions, after being provided with the problem and theory.

Fay provides an effective rubric to determine the amount of inquiry in a laboratory (Fay, 2007). A scaffolded process is determined to be the most effective way to achieve open inquiry. The process would start at a level of minimal inquiry and migrate to more open inquiry, over the timeframe of the study. Inquiry instruction is an important continuum that moves from a highly scaffolded environment to one of a lesser degree as described by National Science Education Standards (NRC, 2000).

The research conducted by Minner, Levy, and Century helps to crystallize the conceptual model of inquiry science instruction. This framework divides inquiry science instruction into three essential components: “(1) the presence of science content, (2) learner’s engagement with science content, and (3) learner’s responsibility for learning, active thinking, or motivation
within at least one component of instruction—question, design, data, conclusion, or communication” (p. 478). (Minner, Levy, & Century, 2010) By separating the three components, measurement of each of the individual components is possible. Additionally, the framework facilitates easy verification that each of the components is present when designing a professional development. Bartos’s contribution to professional development is understanding knowledge of inquiry and its translation into classroom inquiry. Bartos literature article summarizes that instructor knowledge of inquiry doesn’t necessarily translate in the classroom to students (Bartos, 2014).

Sever’s professional development research describes teaching strategies for effective inquiry-based classroom experiments (Sever, 2013). The research results indicate teaching strategies and their associated learning gains (impact). Some strategies have very high levels of effect size and other strategies have lower effect size. Therefore, the most effective strategies can be chosen for professional development. Teaching strategies for implementing inquiry-based instruction are vital to the success of effective professional development. Numerous strategies must be evaluated in terms of constraints including time, audience, and facility. The chosen strategies must take into account constraints and their ability to be easily integrated into the PD model. For example, length of professional development time is vital to consider. Research conducted by Supovitz statistically determines that highly effective professional development is greater than 80 hours (Supovitz, 2000). His study also determines that professional development less than 30 hours has a limited effect on inquiry instruction, due to lack of persistence. Capps (Capps, 2012) has suggested that effective professional development takes at least a week.
The Factor Iterating Inquiry

Iterating inquiry is essential to scientific process and has been found absent in professional development models, as observed in Table 1 above. Chemistry is a science that requires learning through an apprenticeship. “Involvement in scientific inquiry can range from relatively brief classroom activities to lengthy projects in research laboratories.” (Barab & Hay, 2001; Ritchie & Rigano, 1996) This however is not iterative inquiry, as multiple opportunities to engage in inquiry are not achieved. It is generally believed that the more authentic the research experience, such as an apprenticeship guided by a science professional, the more likely students will learn about aspects of scientific inquiry (Bell, 2003). Chemistry is often taught by a series of iterative inquires, the aspect of iterative inquiries is often absent in PD models. Chemistry instruction is designed to begin with an initial inquiry. This initial inquiry creates new inquiries that can be asked and experiments designed to solve the question. This process can continue to be repeated multiple times.

The key elements listed above science content, nature of science, inquiry experience, and iterating inquiry all must be experience in order to have an effective PD experience. Deficiencies in PD’s have been established for each of these key elements in isolation. We propose to blend all of the four critical elements in a carefully constructed PD opportunity.

Our Research Hypothesis

In summary, the first three elements listed above: science content, nature of science, and inquiry experience, all have been identified as being important to an effective PD experience. We propose blending these three factors plus the addition of iterating inquiry. Our hypothesis is that inquiry iteration will lead to increases in teacher scientific communication skills, in use of evidence and reasoning in support of claims, and a deeper understanding of inquiry, and thus a
greater degree of preparedness in teachers. Similarities to an apprenticeship model exist, where facilitation of practical experience by the skilled chemist to the apprentice models the thinking process of the scientist. In chemistry, scientific skills often developed through apprenticeship. Over time, there will be iterative opportunities to communicate, use evidence and reasoning in support of claims, and obtain a deeper understanding of inquiry. However, these opportunities are usually periodic and develop over months or even years. We thought that adding an element of this skill development after each iteration, may speed up this process.
CHAPTER 3

THE DESIGN OF ITERATIVE, INQUIRY-BASED CHEMISTRY ACTIVITIES FOR PROFESSIONAL DEVELOPMENT

Rationale for Professional Development Design

The National Science Teachers Association recommends that all science teachers use instructional practices that support scientific inquiry, in alignment with Next Generation Science Standards that integrate content with inquiry practices (NGSS, 2013). However, research has shown that many science teachers do not have robust understandings and experiences of scientific inquiry (Capps & Crawford, 2013) or may not develop it successfully in their classroom practices (Bartos & Lederman, 2014; DiBiase & McDonald, 2015). Models of professional development for inquiry-based instruction are found in the Capps research critique as well as the work by Loucks-Horsley. These models show three basic factors and we have included a 4th factor, as shown below.

1. Understanding of science subject matter (science content)
2. Learning about nature of science (NOS)
3. Experiencing an inquiry based learning environment
4. Iterating inquiry

Our hypothesis is that inquiry iteration will lead to increases in teacher scientific communication skills, in use of evidence and reasoning in support of claims, and a deeper understanding of inquiry, and thus a greater degree of preparedness in teachers. Although iterating science is an essential feature of the apprentice model, our literature analysis indicates that it has been absent in models of teacher professional development. The apprentice model of
learning is especially relevant when teaching chemistry through conducting laboratory activities (Bell, 2003). To understand whether iteration would be an important addition to the PD workshop model, we designed an iterating set of inquiry-based activities that we suggest may lead to the development of a greater depth of knowledge of scientific practices for teachers and in so doing better prepare them to engage their own students in inquiry in their own classes.

**Proposed Professional Development Improvement**

Our proposed professional development iterates inquiry-based chemistry activities, while taking into account the three factors from the Capps (2013) literature review. Figure 1 below-highlights the sequential steps of our iterative inquiry chemistry workshop design model. The process involves teachers conducting an inquiry lab, with embedded high-level chemistry content during which they collect data and analyze their findings. The teachers then create posters, and share them within their community. The teachers cycle through short inquiry-based chemistry activities iteratively. The iterative design enables participants to experience authentic inquiry in succession to better understand the nuances embedded within inquiry. This repeated exposure to inquiry over a short duration promotes deeper understanding of inquiry.
Figure 1 Sequential steps of the iterative inquiry chemistry workshop professional learning model.

Figure 1 above, depicts the critical steps of the proposed iterative inquiry chemistry workshop. The first step begins with conducting a guided inquiry activity. Examples of activities include CORE (Chemical Observation Representation Experimentation) and other inquiry-based activities (Avargil, Bruce, Amar, & Bruce, 2015; Bruce, Bruce, et al., 2016; Bruce, Wilson, Bruce, Bessey, & Flood, 2016). As multiple cycles are conducted the chemistry activities move towards more open inquiry. The highly scaffolded first phase allows the participants to feel more comfortable with the steps of the process, prior to conducting more complex inquiry; this is very similar to a student’s experience. The familiarity with the sequence of steps by participants (Figure 1) becomes an important aspect of the design. This sequence mirrors the scientific process which is used by scientists to explore ideas. The sequence in the process becomes an important focus of discussion, even though the topics of each inquiry experiment changes. The teachers have an opportunity to see how the steps interact with each other in the discovery
process allowing the process to emerge as an important feature of doing science (e.g. teachers asking hard questions of each other even if you do not know the answers, making contributions to other people’s work, thinking about how to tell a scientific story in terms that other people will understand, etc.) This permits participants move to more open-ended inquiry, as teachers articulate their thought process with each other.

Step 1, Inquiry (guided and open) of each cycle. Participants are given a (30-90 min.) short inquiry-based chemistry exploration? Groups of (3-5) teachers must arrive at a consensus about what to measure and how to perform the experiment.

Step 2, Data Collection. In the initial iteration, the data table is provided with column headings to minimize teacher’s thought process, however as the participants progress to open inquiry the data collection becomes more complex. Typically, teachers must discuss how much data to collect (e.g. should they include temperature, humidity, and other varying details).

Step 3, Data Analysis and Claims. This step requires each group to consider the data that was collected and to process it. As teacher became more familiar with the iterative process, the types and quality of questions changed, with self-questioning within the groups becoming more apparent. What claims can we draw from the data? Does more data need to be collected to establish a trend? What is the most effective way to analyze our data? What statistical analysis should be performed on the data? These questions sometimes lead to more collection of data and often had implications for what was needed to present the scientific results to other groups.

Step 4, Poster Creation and Presentation. Very little instruction was given to teachers about how or what to present in their posters. Even though many of the participating teachers had
many years of teaching experience, the quality of the initial posters was in many cases poor. It was not until step 5 (vide infra), that many of the teachers started to recognize that the questions they had of other groups, were not being addressed in their own posters. As the posters were iterated, the poster creation process changed in terms of the groups asking each other hard questions before they started to create the poster, became more strategic in how to organize the information on the poster, adding addition sections to the poster, or adding more physical space to the poster. This reflective practice developed appears to have developed in some significant way because of the community discussions (see below).

Step 5, Community Discussion. Scientific results are communicated in a peer community where judgements about approaches, the quality of evidence, analysis, and claims are made. It is hard to simulate this aspect of science, but each participant in the professional learning community can be energized to help each other piece together experimental inquiry. This is done by setting norms about respect, but also talking about the role that hard questions have in science – when there may not be any easy, immediate answers. The community can be asked to make a collective judgement about the validity of the data collected, especially in the context of experiments where procedures are created. The community can also be asked to present constructive ideas that could be used to improve the science. The idea of empowering the collective group, rather than having everyone turn to an “expert” is an important concept in order to develop an opportunity for participants to learn science. The person leading the PD was an “expert”, and his role initially was to open up the questioning with questions that suggested some deficiencies in the presented work. An example is, do we think that the evidence being presented is sufficient to make the claim that is being formulated? Or, there is a claim, does the evidence really allow this claim to be made? The community also needs to know that science is socially
constructed, and that communication is a vital part of learning inquiry. After a few initial questions, the “expert” encourages others to ask questions. In this way, the role of the “expert” diminishes with each iteration. This can be facilitated by encouraging the participants to ask good which can be used to “push” the level of science to a higher level. The presentation of work by each group then becomes an opportunity to assess what the community thinks of the presented work and opportunities towards improvement. This community aspect plays a vital role in the iterative inquiry chemistry workshop; all members of the cohort are expected to contribute during the community discussion.

**Iterative Nature of Chemistry Workshop**

The iterative inquiry chemistry workshop is designed to facilitate a deeper understanding of scientific inquiry. Establishing a deeper understanding of inquiry is critical to educators and students alike; but inquiry is difficult. The CORE (Chemical Observations, Representation, and Experimentation) approach to inquiry, shares distinct similarities to our proposed iterative inquiry chemistry workshop (Avargil’s, 2015). The similarities include, participants conducting an inquiry lab, with embedded high-level chemistry content. The participants also communicate scientifically by using analogical reasoning connecting the submicroscopic to the macroscopic world. A key feature of CORE learning cycle is the opportunity for students to coordinate information about what they observe in the lab and a representation (e.g. model) to foster the connection of ideas across domains of knowledge (macroscopic to submicroscopic). Throughout the spectrum of professional learning activities (content presentations, clicker questions and discussions, demonstrations, laboratory experimentation, poster creation and presentations, and an assignment to read a chemistry education (Johnstone, 1993), participants were encouraged to
think about what representations they could use, and the idea that a representation allows coordination of information across domains.

**Important Aspects in Planning of Iterative Inquiry Chemistry Workshop**

In designing the PD, we recognized that scientific communication, group dynamics among teachers, and developing a deeper conceptual understanding of the connection between macroscopic observations and submicroscopic atomic scale chemistry would be critical aspects of the PD workshop. Accordingly, these aspects were integrated into the iterative inquiry-based PD workshop as detailed below.

1. Scientific Communication
2. Group Dynamic
3. Deeper Conceptual Understanding at Submicroscopic Level

**The Aspect of Scientific Communication**

During the iterative inquiry chemistry workshop, the proposed study takes into account teachers’ scientific communication, one of the practices of scientific inquiry. Scientific communication is an inquiry practice that includes sharing findings within the scientific community as a crucial part in the development and refinement of scientific ideas. (Halonen, 2003) Step 5 (Figure 1), built into the workshop design multiple opportunities for the community (i.e. everyone involved in the PD, K-12 teachers, MST graduate students, and faculty leading the workshop) to assess the quality of their peer’s poster.

In order to effectively communicate, participants were asked to compose and present their finding in an orderly, logical fashion that is capable of being understood by the audience
Communication skills are vital in the advancement of a scientific community (Saavedra, 2012) and this was stressed in the initial discussions of why participants were doing this activity iteratively. Thus, our approach towards developing a deeper understanding of scientific communication skills was to practice it iteratively, in somewhat difference contexts each time it was required of participants.

Because of the importance of communicating scientific ideas sufficient time was built into these activities so that participants could critique what their peers did, discuss what evidence was collected, what claims were being made, and discuss if claims were substantiated with evidence. A theme throughout the poster discussions was to compare findings across groups (e.g. looking at different posters) and to discuss why groups included certain information in their presentations. It should be noted again that each group did not design exactly the same experiment (e.g. during stage 3 of a CORE lab), so that procedural differences among groups and how choices of what and how to experiment influenced were often discussed.

**The Aspect of Group Dynamic**

The group dynamic is impacted by all stakeholders in the iterative inquiry chemistry workshop. Body language, positive/negative disposition, facial expressions, as well as a multitude of behaviors affect the group. These interactions can be either supportive or detrimental to the group dynamic. In order to achieve the desired group dynamic, the leaders must demonstrate positive behavior, and facilitate cohort’s behavior (Gajda, 2017).

An important aspect of the group dynamic is to develop leaders for subsequent peer led group discussions (Eichler, 1987), as the cohort moves through the iterative inquiry chemistry workshop, careful consideration of the group dynamic must be utilized in planning workshops.
Leadership skills and group dynamics can be scaffolded (Harper, 2015) through the training experiences. In the research conducted by Harper, undergraduate students, who are members of a peer led group, receive leadership training as members of a group. As peer facilitators these students exhibit skills obtained during both their practice as leaders as well as during their role as a group member.

Four important norms must be developed during the iterative inquiry chemistry workshop:

1. comfortable environment
2. safe space to articulate thoughts
3. investment in the group both for giving and receiving feedback
4. constructive criticism during discussions

A constructive group dynamic must be cultivated in order to have fruitful discussions during the workshop. The iterative cycling allows a stronger sense of developed community to form. This is vital in the group dynamic for cohort members to feel comfortable communicating scientifically, an inquiry component. Throughout the weeklong endeavor, groupings of teachers are held constant to strengthen their relationships and comfort in expressing their thoughts and ideas. The community aspect of group dynamic must be fostered in a positive supportive forum; it is a delicate task that requires mature audiences that understand the purpose of constructive criticism. Students and instructors alike need to understand how to effectively accept and give constructive criticism.
The Aspect of Deeper Conceptual Understanding at the Submicroscopic Level

During the proposed iterative inquiry chemistry workshop, appreciation of deep conceptual understanding at the submicroscopic level is an important aspect. Chemistry is unique as the majority of topics are taught through analogies and observable macro reactions. Thus models are of great importance in chemistry. Sensitivity to the difficult conceptual connection between the submicro and macro world is necessary when planning appropriate workshop activities. Bruce’s (2016) work on Polymers and Cross-Linking provides a bridge between the macroscopic and microscopic world. Specifically, in Bruce’s work, paperclips, the real world macro example are analogically linked to the poly vinyl alcohol and sodium borate cross-linking in the submicro world to form slime. To promote deeper conceptual understanding at the submicroscopic level it is vital to facilitate teacher’s connection between submicro and macro world during the iterative inquiry chemistry workshop.

In an additional example, Avargil’s (2015) cyclical CORE structure integrates inquiry with macro and submicro analogical reasoning. Analogical reasoning is effective in helping to visualize a process that occurs at the unobservable level (submicro) by utilizing a real world example (macro) to bridge the chemistry concept. Analogical reasoning provides the linkage between the macro and submicro world, facilitating a deeper level of conceptual understanding.
CHAPTER 4

WORKSHOP DESIGN: ACTIVITIES CONDUCTED FOR PROFESSIONAL DEVELOPMENT AND THE DATA COLLECTED FOR ANALYSIS

Context of Research and Workshop Design

The Maine Physical Sciences Partnership (Maine PSP) was funded by the National Science Foundation (NSF; 0962805, 2010-2016) as part of the Math and Science Partnership (MSP) program. The Maine PSP project brought together forty-two rural Maine schools, the University of Maine, three Maine non-profits with expertise in science education, and science and technology leaders at the Maine Department of Education to target the teaching and learning of physical sciences in grades 6-9. A major initiative of the Maine PSP was to coordinate community-wide selection of vertically aligned research-based physical science curricular materials to be implemented across partnering school districts. The project operated from 2010-2016 and offered hundreds of hours of professional development opportunities for K-12 and University faculty.

The Maine PSP offered a Maine Summer Academy in 2014 for more than a hundred K-12 teachers, including content PD workshops in areas such as chemistry and physics. The 2014 Chemistry Summer Academy strand included ten middle and high school teachers from rural schools participating in the MSP. Many of these teachers had either taught using the MSP-selected curricular materials for Chemistry (the first two modules of SEPUP Issues and Physical Science) in the previous year or were preparing to teach it in the coming school year. Half of the teachers were male, half were female, and all were Caucasian. The teachers were diverse in their teaching experience, ranging from one to over twenty years. Participants had self-selected for the
workshop, having been given a choice of two strands of Physical Sciences PD. Pre-service teachers also participated in the PD, but are not a focus of this study.

Workshop participants in the Chemistry Summer Academy strand included ten current practicing teachers from the greater Bangor and surroundings areas. In addition to the teachers, there was a long-term substitute teacher, three undergraduate University of Maine students, and two masters in science education students. A University of Maine faculty member led the workshop.

Participants were divided into four small groups at the start of the four-day workshop and worked in these groups to conduct multiple inquiry-based, facilitated Chemistry investigations throughout the week. The iterative inquiry chemistry workshop was held at the Schoodic Education and Research Center (SERC) located just outside the village of Winter Harbor, Maine. The cohort arrived on Monday night and spent 3.5 days at the SERC facility which includes housing. The cohort was sequestered at SERC during the weeklong workshop to allow for group collaboration. All meals were taken together among all of the Maine Summer Academy participants, workshop leaders, and associated project staff. The classroom used to deliver the workshop training consisted of 6 tables, a whiteboard and projector at the front of the room, along with a desk for the instructor, in a typical classroom format. There was an adjoining laboratory for performing the inquiry based laboratories.

The iterative inquiry chemistry workshop was designed around two areas. The first area involved content that was delivered through presentations, clicker questions, discussions, and demonstrations facilitated by the workshop facilitator, a chemistry faculty member for the University of Maine. These activities conveyed the importance of content and examined some of the theories of learning involved in making macroscopic to submicroscopic connections. The
other area of professional development was done through a series of inquiry-based laboratory activities. Following the activity, teams discussed results, formulated claims, constructed a poster, presented and discussed it with other workshop participants.

Table 1 shows the overall schedule of the Workshop. Participants engaged in a series of activities during the iterative inquiry chemistry workshop. Integrated into the schedule includes data (e.g. surveys, posters) that were used for evaluating the level of engagement and participant outcomes. These are discussed in turn below.

Table 1 Schedule during the 2014 Summer Academy Chemistry Workshop

<table>
<thead>
<tr>
<th>Tuesday 6/24</th>
<th>Wednesday 6/25</th>
<th>Thursday 6/26</th>
<th>Friday 6/27</th>
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<tbody>
<tr>
<td><strong>Morning</strong></td>
<td><strong>Morning</strong></td>
<td><strong>Morning</strong></td>
<td><strong>Morning</strong></td>
</tr>
<tr>
<td>Intro; Clicker Questions; Pre Survey</td>
<td>Presentation- Density</td>
<td>Activity– Polymer Lab (POSTER 3)</td>
<td>Current Slime Research Quantum Numbers</td>
</tr>
<tr>
<td>Presentation: Electron Configuration</td>
<td>Activity- Oxidation/Reduction</td>
<td>Johnstone macro micro triangle (POSTER 4)</td>
<td>Activity – Homo, Lumo e' configuration 1s22s23p6…</td>
</tr>
<tr>
<td>Clicker Questions w Discussion</td>
<td></td>
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</tr>
<tr>
<td>Presentation: Electron Configuration – exercise – molecular orbital diagrams</td>
<td>Looking at Student Survey Data and Thinking (Pre-Post Data)</td>
<td>Presentation: Experimental chemical research</td>
<td>Isomers, VSEPR theory II Activity: Wintergreen-Life Savers</td>
</tr>
<tr>
<td>Demo: Liquid N₂ and O₂ with Magnet (Explanation not in our macro world)</td>
<td>Discussion- Student Survey – Implications to Teaching Practices</td>
<td>Presentation: Experimental chemical research (cont.)</td>
<td>Concluding Discussion Post Survey WORKSHOP ENDED</td>
</tr>
<tr>
<td>Afternoon</td>
<td>Afternoon</td>
<td>Afternoon</td>
<td>Afternoon</td>
</tr>
<tr>
<td>Activity – Inquiry Lab-Soda Challenge (POSTER 1)</td>
<td>Analogical Reasoning Research results</td>
<td>Activity – Elephant toothpaste (POSTER 5)</td>
<td></td>
</tr>
<tr>
<td>Presentation: Multi-modal Learning in Science</td>
<td>The Scientific Method-Thinking like a Scientist: Discussion</td>
<td>Activity- Oxidation/Reduction</td>
<td></td>
</tr>
<tr>
<td>Activity – Density Lab (POSTER 2)</td>
<td>The Scientific Method-Thinking like a Scientist: Discussion (cont.)</td>
<td>Demo and Predictions: Ethanol and Water</td>
<td></td>
</tr>
<tr>
<td>Discussion - Error</td>
<td>The Scientific Method-Thinking like a Scientist: Discussion (cont.)</td>
<td>Activity – Balloons VSEPR Theory I: electronic structure</td>
<td></td>
</tr>
</tbody>
</table>
Activities Conducted for Iterative Inquiry Chemistry Workshop

Content Presentations, Theory, Clicker Questions, Discussions, and Demonstrations

The workshop offered a variety of activities that were focused on content information and discussions of deficiencies in understanding. The activities include content presentations, educational theory, clicker questions, discussions, and demonstrations that were cycled throughout the workshop. Table 1 displays the schedule and structured sequence of each activity. There was approximately 28 hours of PD during the workshop.

Short content presentations conducted by the facilitator were presented in a lecture style format integrating clicker questions and small group discussions. The presentations engaged teachers in high level content in order to connect with chemistry concepts that build upon middle and high school curricula. Density, electron configurations and VSEPR are a few of the high level chemistry concepts presented during the workshop, to engage and stretch the cohorts’ chemistry understanding.

Educational theories were explored in the context of learning complex chemistry concepts. The broad theory of analogical reasoning was presented; in the context that it can facilitate chemistry phenomena understanding. Thinking like a scientist is another theory explored during the PD, to illuminate scientific skills. Discussions around these theories facilitate teachers’ transition; from “teaching chemistry content” to deepening chemistry concept understanding and metacognition (thinking about one’s thinking.)

Complex chemistry concepts were introduced and discussed utilizing clicker questions. These high level questions required group discussions to reach correct solution. Complex chemistry concepts that are beyond the scope of the instructor’s curriculum are intentionally
interwoven to challenge participants thinking and to facilitate “thinking like a student”. The clicker questions also illicit peer-to-peer discussion to confront misconceptions.

Discussions were iterated throughout the workshop, both as discrete activities, e.g. embedded within activities, as well as student survey data (student survey results captured to analyze for learning gains). Discussions were purposefully integrated during presentations, to encourage rich discussions. For example, during and after clicker questions, conversations occurred as to the chemical concept used to evaluate the question. A discrete activity denoted in the workshop was a group discussion facilitated by a University of Maine graduate student focused on student survey data and research findings from the Science Education for Public Understanding (SEPUP) curriculum. This included data from some of the teachers participating in the workshop.

Demonstrations were also conducted to engage workshop participants and help deepen their chemistry understanding. A demonstration involving liquid nitrogen to distill and collect liquid oxygen, and the testing of liquid nitrogen and oxygen in a magnetic field, engaged teachers in connecting observations of these substances in a magnetic field and descriptions of the substances using molecular orbital theory, to coordinate thinking about making macroscopic to submicroscopic connections. Additionally, a demonstration involving predictions about total volume when combining equal parts water, alcohol, and water + alcohol (1:1) was conducted to challenge ideas about modeling (e.g. role and interaction of solvent in chemistry and refining ideas about models).

**Iterated Inquiry Activities, Poster Construction, Presentations and Discussions**

Iteration of inquiry based activities is the fourth component proposed by our research team. Inquiry laboratories were iterated throughout the workshop, as shown in Table 1.
Participants were tasked with completing inquiry based laboratories. Teams constructed posters to present their experimental findings at the end of each inquiry activity.

The posters were presented during step 5 (community discussion) of our iterative inquiry based activity design. The presentation component of the cycle requires groups to conduct a gallery walk and then provide feedback and questions to the other groups. The community discussion portion of our iterative design facilitates scientific poster discussions. Discussions were iterated throughout the workshop, both as discrete activities as well as embedded within the inquiry-based laboratory iteration.

**Design of Data Collected for Analysis**

In order to assess our iterative inquiry chemistry workshop’s effectiveness, we selected several modes of measurement. Knowledge of established research literature and the instruments used in their research was necessary to inform our research. Three publications by Akerson (2007), Blanchard (2009) and JeanPierre (2005), from the Capps et. al. (2012) literature review are displayed in Table 2. The research literature author along with the data instruments used to measure their research questions’ effectiveness are illustrated.

Table 2 Professional development data instruments from Capps et. al. 2012 and the Summer Academy, an “X” signifies data included in the PD.

<table>
<thead>
<tr>
<th>Author</th>
<th>Pre and post surveys</th>
<th>Teacher interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akerson (2007)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>JeanPierre (2005)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Blanchard (2009)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Summer Academy Professional Development</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Commonalities exist between types of data collected for established research as illustrated in Table 2. The commonalities between our research and the authors include the data instruments listed in the table above. Pre and post surveys and teacher interviews are evaluative data instruments conducted during our iterative inquiry chemistry workshop. We have also included inquiry based posters as a source of data. Data collected and the purpose for its collection is included below in Table 3:

Table 3 Data collected during /after iterative inquiry chemistry workshop

<table>
<thead>
<tr>
<th>Data</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre and post surveys</td>
<td>Insight into scientific understanding - Experience gained during workshop</td>
</tr>
<tr>
<td>Inquiry based posters</td>
<td>Treatment – vehicle for scientific communication during iterative inquiry chemistry workshop</td>
</tr>
<tr>
<td>Teacher interviews</td>
<td>Short term/ long term impact on instruction</td>
</tr>
</tbody>
</table>

Table 3 illustrates the data collected during and after the iterative inquiry chemistry workshop and its purpose. Pre and post surveys provide insight into teacher’s scientific understanding and provide qualitative data to determine experience gained during the workshop. The posters created at the conclusion of each inquiry based laboratory explicitly display the teachers’ findings and are used to facilitate a scientific community poster discussion session. The short and long term teacher interviews attempt to illuminate the impact on teacher’s instruction, as it pertains to strategies and techniques learned during the workshop. The data collected was used to evaluate our research questions.
CHAPTER 5
RESULTS AND DISCUSSION

Overall Goals of Research

The research focused on three major questions related to the teacher professional development iterative inquiry-based Chemistry workshop that was conducted with K-12 teachers:

1. What was the effect of the professional development on teacher’s scientific communication skills?

2. In what ways did the professional development affect the use of evidence and reasoning in supporting claims?

3. What was the effect of the professional development on teacher’s understanding of inquiry?

Posters, surveys, and interviews, comprise the corpus of the data to address these questions. The iterative inquiry-based chemistry activities concluded with a poster after each cycle. The iterative nature of the workshop was achieved through repeating the cycle in Figure 1 multiple times. The cohort completed a pre-workshop and post-workshop survey. Teacher interviews, recorded and transcribed, were conducted after the workshop at different time intervals.

This chapter provides an integrated look at the evidence, methods, analysis and discussion to assess each research question. The chapter concludes with a discussion of findings, which is continued in chapter 6 where the findings are summarized and future work is discussed.
Posters

Each cycle of the inquiry-based activity provided teachers an opportunity to collaboratively state their findings in a poster. Each activity included an introduction with science articles and/or facilitated discussion of chemistry concepts. The inquiry activity was conducted and then a poster and presentation ensued. The poster design and presentations occurred five times in the 32-hour chemistry workshop in an effort to repetitively engage participants in the inquiry process. Table 4 below lists the activities and their estimated level of inquiry as measured by Bruck (2008).

Table 4 Chemistry workshop poster number, inquiry activity name, and estimated inquiry level using the criteria of Bruck (2008).

<table>
<thead>
<tr>
<th>Poster #</th>
<th>Inquiry Activity</th>
<th>Estimated Inquiry Level *</th>
<th>Provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soda Challenge</td>
<td>Level 1 (Guided Inquiry)</td>
<td>Procedure</td>
</tr>
<tr>
<td>2</td>
<td>Density/ Dissolution</td>
<td>Level 1 (Guided Inquiry)</td>
<td>Procedure</td>
</tr>
<tr>
<td>3</td>
<td>Slime</td>
<td>Level 2 (Open Inquiry)</td>
<td>Background</td>
</tr>
<tr>
<td>4</td>
<td>Johnstone’s Triangle</td>
<td>Level 2 (Open Inquiry)</td>
<td>Background</td>
</tr>
<tr>
<td>5</td>
<td>Elephant’s Toothpaste</td>
<td>Level 3 (Open to Authentic Inquiry)</td>
<td>Materials</td>
</tr>
</tbody>
</table>

Activity 1 – Soda Challenge

As an intro to the iterative inquiry chemistry workshop, the participants met on the first morning of the workshop and were involved in an icebreaker activity. The icebreaker activity focused on the atomic level and required participants to intentionally think about electron configuration. The prompt was “describe as many ideas about electron configuration as you can in five minutes.” An electron configuration exercise was conducted directly after observing a demonstration of condensing liquid oxygen from the air. The purposes of the icebreaker, exercise and demonstration were to have participants feel comfortable and focus on the atomic
level, through observable macro chemical phenomena and representation. This was a new way of thinking for some participants.

After the icebreaker, exercise, and demonstration, participants were tasked with conducting an inquiry-based lab, the Soda Challenge. The lab requires participants to predict whether an unopened soda can would sink or float in a fish tank filled with water. Multiple types of soda were provided including Coke, diet Coke, Pepsi, and diet Pepsi. Necessary laboratory equipment was made available to teachers to design and conduct a buoyancy experiment. After the experiment, a poster was created with limited input from the advising faculty member. The posters were then placed on display, and teachers conducted a gallery walk, followed by a community discussion. The discussion was an important part of the treatment.

During the discussion, the teachers and student participants did acknowledge, without too much prodding, that the posters seemed inadequate for explaining the science behind the activity. The advising faculty asked a few hard, but respectful questions. The teachers seemed to catch on very quickly, that by asking questions that were hard to answer, this provided a strategy that uncovered deficiencies in the logic being presented. Some participants, who were a little embarrassed by have a weak poster, understood that they were being encouraged to ask the same sorts of hard questions of other groups. This set the tone for a respectful, but comprehensive scientific discussion. This practice grew stronger during the week, and this treatment seems important to the improvement seen in subsequent posters. No formal “rules” were established outside of (1) being respectful, (2) if you don’t understand something or it doesn’t make sense, speak up, and (3) to help each other figure out the answers to “hard” questions being asked.
Activity 2 – Density/Dissolution

The following day, the cohort read a science literature article (Waldrip, 2010), and a question was posed to the teachers. What makes for a good science article? The purpose of the article and the subsequent discussion was to aid teachers in the self-reflective process. After discussing this question in a collaborative format, teachers began to critique writing more critically. This also appears to have increased teacher’s ability to realize deficiencies in the posters. The deficiencies became apparent in the community discussion through the insightful questions being asked.

An additional article, whose topic was on multi-modal science communication, was offered to teachers as a way to facilitate understanding of the necessary components in an effective science article; including multi-modal text, figures, graphs, tables, and images. A collaborative discussion was conducted encompassing multimodal forms of representing a phenomenon. Teachers were given a choice in activities; they could choose to conduct either the density or the dissolution laboratory. Three of the four groups chose to perform the density laboratory (see appendix 7). At the conclusion of the experiment, a poster was created. The posters were displayed around the room, teachers critiqued each poster and then there was a community discussion.

As the first poster discussion reinforced thoughtful discussion, there appeared to be a deepening in the importance of the poster activity. The advising faculty member had commented that communication was an essential practice in science, and that the “peer” community stood in judgment of what was accepted in science. All of the participants in the workshop were now a “peer” community. These statements were intended to empowered teachers. The discussions appeared to take on a more serious tone.
Activity 3 – Slime

To begin the third activity, teachers collaboratively discussed whether each poster from the previous two inquiry activities had explicitly stated evidence, reasoning, and claims. The community discussed the importance of each of these three components. A theme of this discussion was that communicating these features took skill and practice. Each of the groups was asked to discuss and report out a critique of posters (in general – all of them) and their rationale for determining the strength or weakness of each poster. During the discussion, it became apparent that in evaluating their own work, that their posters were not explicitly stating evidence, reasoning, and claim. This self-realization of deficiencies in evidence, reasoning and claims, crystallized for participants their inability to communicate their results.

The concept of oxidation and reduction was introduced to the cohort through direct instruction using a slideshow presentation. There were complex chemistry content questions embedded within the presentation and the questions were answered using individual clickers that had been distributed to each teacher. Some of the participants revealed that they did not know much about this area of chemistry. The advising faculty presenter discussed that this was not an unusual situation, i.e. that people had different strengths and weaknesses. The idea of teamwork, to utilize the talents of the team was also discussed. We should note that most teams had embedded graduate students who had taken chemistry recently, who could act as a resource for teachers.

Subsequently, the teachers were presented middle school student data, from a study conducted in a previous year, to analyze and discuss. The student survey data was from grades 6-8, that was collected pre and post instruction. The survey involves concepts such as density and
conservation of mass. The “research” involved analyzing the data and proposing modifications that might be enacted in future research. The student data had been collected by some of the teachers participating in the iterative inquiry chemistry workshop. This helped foster a collaborative discussion amongst teachers. The question was asked, what would help you instruct inquiry in the classroom? Additionally, the question was posed, would it be beneficial if you were made active participants in the current research being performed, for instance the design of the survey instrument itself? A group wide discussion ensued that facilitated connecting teachers to the current professional development they were taking part in.

After a group wide discussion around these questions, teachers were provided an inquiry-based laboratory experiment procedure that was similar to what was eventually published as Polymers and Cross-Linking CORE experiment (Bruce, 2016). The activity involved mixing aqueous solutions of polyvinyl alcohol and sodium borate to produce a material that is commonly called “slime”. The majority of the teachers had encountered making slime as an outreach activity, however, this version asked participants to design some experiments, an aspect that many teachers had not been asked to do before. The groups were required to conduct a higher level of inquiry as displayed in Table 4, Level 2 (open inquiry); as they had to identify a measureable variable. The increased level of inquiry and the associated difficulty was evident based on discussions revolving around claim based reasoning and creating data for their poster. At the conclusion of the experiment, a poster was created. The posters were taped to the walls, teachers conducted a gallery walk to critique the posters and then community discussion took place.

This community discussion focused more on the robust presence of multiple visual appealing charts, tables, and figures. An increasing number of charts, tables, and figures were
included in the posters and used to convey data and claims. Teachers observed these changes and commented on their presence as well as what they conveyed. One group even used a chain of paperclips taped to their poster as a representation of the cross linking polymer.

**Activity 4 – Johnstone’s Triangle**

A science article, “The Development of Chemistry Teaching - a Changing Response to Changing Demand” which includes a diagram often referred to as Johnstone’s triangle (1993) was briefly introduced and time was provided to read the article. The Johnstone’s triangle article succinctly describes the connection that spans the submicroscopic and macroscopic domains using a representation. Several teachers appreciated the explicit nature of the triangle and ideas about how to connect abstract thinking (submicroscopic), concrete thinking (macroscopic) and the underlying representation which is involved in making a connection. In addition, the facilitator described research efforts over a period of decades to give some perspective how research uses evidence and representations to think about claims, and that over time, representations can be refined in an approach similar to that described using the Johnstone’s triangle paper. This was achieved by citing publications and displaying current research being conducted. Finally, triboluminscence was observed in a video found online, the chewing of wintergreen candy. The observed light emission involving triboluminscence was described by the facilitator as the relaxation to the ground state following electron promotion to an unstable state. A representation of the phenomenon was drawn on the board to aid in visualization.

For the fourth poster, teachers were tasked with creating a poster encapsulating the three realms submicroscopic, macroscopic, and representation. The instructions were to use any conceptual understanding that could be visualized through Johnstone’s triangle. Prior to teacher’s exposure to Johnstone’s triangle, per data from interviews, the teachers had limited familiarity
with ideas surrounding connecting the submicroscopic and macroscopic using representations. The posters were displayed, teachers viewed their colleague’s posters and then a community discussion ensued. The poster provided an opportunity for teachers to discuss how connections were made.

The community discussion focused on Johnstone’s triangle and the explicit connection between submicroscopic and macroscopic using representations. Teachers became increasingly complimentary of each groups unique way of displaying a chemistry concept using the Johnstone's triangle framework.

**Activity 5 – Elephant Toothpaste**

The iterative inquiry chemistry workshop facilitator revisited the slime lab, bringing teachers up to date with an area of polymer research that overlaps with the activity they had done using an article, published in the Journal of Applied Polymer Science. The research created additional questions from the cohort requiring a brief discussion of quantum numbers. The purpose for the slime research literature was to allow teachers to understand that chemistry’s complexities were not yet fully understood. In other words, there was not a complete understanding of phenomena/experiments that have been taught for decades, and that the field of chemistry still had an evolving understanding of aspects of the dynamic properties of “slime”.

After an in-depth discussion following the Johnstone’s triangle poster session, a new laboratory was introduced. The discussion reiterated the importance of connections between the submicroscopic and macroscopic worlds using representations. Participants discussed the explicit nature of the triangle and how it deepened their understanding of the connection, and provided them with a tangible framework for explaining topics spanning submicroscopic and macroscopic.
Elephant’s Toothpaste laboratory was a kinetic study between the reaction of potassium iodide and hydrogen peroxide. Prior to beginning the inquiry-based laboratory, each group had to identify a measurable variable (Level 3 Authentic Inquiry). Thus, the specific problem or question they wanted to address was chosen by each group. They were also encouraged to fill in any “gaps” they had about the theory/background, in order to explore this chemical system. At the conclusion of the experiment, a poster was created. The posters were then placed on display, teachers conducted a gallery walk and then a community discussion ensues.

The community discussion was unique for a variety of reasons. Only two of the groups chose to create posters. During the poster session, one of these groups presented a short video. The unique use of a different medium (video) other than posters used during the discussion effectively provided evidence in support of their claim. The discussion focused on the unique way the group chose to present their findings, as opposed to the typical gallery walk style. In the figures below, each of the workshop posters are included.
Claim: Soft drinks with artificial sweeteners are less dense.

Evidence: All diet soft drinks were more buoyant. Calculated densities.
Two Methods for Determining Density

Method 1

1. We measured the volume of the rectangular prism of clay in centimeters.
2. Next we calculated the volume: (7.4 cm) x (2.5 cm) x (3 cm)
   \[ V = 62.1 \text{ cm}^3 \]
3. We weighed the prism, finding the mass to be 113.75g
4. Finally, the density was determined to be 1.83g/cm³
   \[ D = \frac{113.75 \text{ g}}{62.1 \text{ cm}^3} \]

Questioning what would happen if we cut the clay in half, we repeated both our methods for density determination again.

Method 2

1. Volume = 12.7cm x (8.5cm) x (2.4cm) = 310.08 cm³
2. Remeasured mass to be 57.058 g
3. So density = 1.89 g/cm³

Completed by “Gloria”!

*Claim*

- Both methods are viable with available tools

*Evidence*

1.83 g/cm³

*Reasoning*

Both methods produce results that are statistically indistinguishable.

Figure 3 Sherry’s poster from iterative inquiry chemistry workshop Poster 2 (Density)
Proportions of Reactants Affect Material Properties

**Introduction:**
- Polymers are many monomers linked together.
- Polymers are used in many fabrics and materials today.
- Industrial research attempts to create more durable, effective fabrics.
- Figure 2 depicts cross-linking polymers.
- Increases in cross-linking increases viscosity.

**Purpose:**
- **GLORIA TEAM** wanted to determine the saturation point of the combination of sodium borate and polyvinyl alcohol. We varied the ratio of PVA and sodium borate in order to determine the saturation point.

**Procedure:**
1. Measure with graduated cylinder amount of PVA (mL) (see Table)
2. Measure with graduated cylinder amount of sodium borate (mL) (see Table)
3. Mix PVA and sodium borate + stir

**Figure 1**
- After mixing, place slime in 45 mm Nalgene Funnel and time (min. sec.) how long it takes to empty the funnel, see Fig 3
- Record time in Table 1

**Table 1**

<table>
<thead>
<tr>
<th>Physical Amount</th>
<th>Sodium Borate</th>
<th>Ratio</th>
<th>Time to Empty (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 mL</td>
<td>5 mL</td>
<td>1:1</td>
<td>10.5</td>
</tr>
<tr>
<td>6 mL</td>
<td>3 mL</td>
<td>2:1</td>
<td>12.8</td>
</tr>
<tr>
<td>6 mL</td>
<td>2 mL</td>
<td>3:1</td>
<td>45.30.0</td>
</tr>
<tr>
<td>20 mL</td>
<td>5 mL</td>
<td>4:1</td>
<td>11:55</td>
</tr>
<tr>
<td>1 mL</td>
<td>10 mL</td>
<td>1:10</td>
<td>0:01.3</td>
</tr>
</tbody>
</table>

**Figure 2**

**Figure 3**

Clay:
- As the ratio of Sodium Borate to Polyvinyl Chloride increases the viscosity of the slime decreases.

**Reasoning:**
- We tested different ratios of reactants and found that as we increased the amount of Sodium Borate the resulting substance got thinner (i.e., had a lower viscosity).
- We observed this phenomenon while pouring the substance through a funnel and measuring how long it took for them to flow through.

Figure 4 Sherry’s poster from iterative inquiry chemistry workshop Poster 3 (Slime)
Figure 5 Sherry’s poster from iterative inquiry chemistry workshop Poster 4 (Johnstone’s Triangle)


Group 1A

- Prediction: Regular Pepsi and Coke would both sink, Diet Pepsi and Diet Coke would float.

- Results: Qualitative - Pepsi sinks all others float.

  Quantitative - Everything should have floated since volume is greater than mass.

- Discussion: Qual. and Quant. results do not match.

  Methods of measuring volume were not accurate.
**Dissolution of Substances**

**Results:**

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soluble in Cold Water</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Appearance</td>
<td>Granular</td>
<td>Powder</td>
<td>Powder</td>
</tr>
<tr>
<td>Exothermic</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

**Procedure:**

Round 1: Dissolve 1g of each unknown solid into 50mL of cold water and swirled for 1 minute.

Round 2: Place minimal amount of substance C into 50mL. Placed 1g of substances A and B into respective beakers and added 2mL aliquots as needed.
Claim:

- All 3 substances are different
- Substances A and B are polar compounds
- Substance C is a non-polar compound

Group LA
Making Chemical Observations

How does the ratio of Polyvinyl Alcohol to Sodium Borate change the viscosity of the slime?

5 mL Sodium Borate → 20 mL Polyvinyl Alcohol

Claim: Increasing the ratio of PVA to Sodium Borate will decrease viscosity. The solution was created twice in this experiment; one with a lower ratio than the initial solution.

Using the first solution's viscosity as a control/standard, the viscosities of the two new solutions were compared.

Findings: Claim was not supported during experiment. Increasing the ratio of PVA to Sodium Borate increased viscosity while decreasing the ratio of PVA to Sodium Borate decreased viscosity.

Hypothesis: Further studies

When considering the paperclip analogy, the more PVA that was added, the concentration of sodium borate, the more cross-linking occurred.
Figure 10 Uno’s poster from iterative inquiry chemistry workshop Poster 4 (Johnstone’s Triangle)
**Brush with Disaster**

**Q:** How does varying concentration of H$_2$O$_2$ affect rates of decomposition?

**Prediction:** Higher concentration of reactant will increase the rate of reaction.

**Procedure/Results:**

<table>
<thead>
<tr>
<th>Trial</th>
<th>$[\text{H}_2\text{O}_2]$ (w/v)</th>
<th>Vol. Soap (mL)</th>
<th>Vol. KI (mL)</th>
<th>Vol. H$_2$O$_2$ (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3%</td>
<td>5</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>15%</td>
<td>3</td>
<td>10</td>
<td>10.8</td>
</tr>
<tr>
<td>3</td>
<td>30%</td>
<td>3</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

**Evidence:** video confirms prediction.
Results - A2

- We found that Pepsi sank while the other three floated.
- Diet sodas floated higher than the regular cokes.
- The Pepsi gradually sank.

- Procedures:
  - placed each soda in at a time - vertical
  - Each can was removed before placing the other in

- Claim: Pepsi sank due to increased sugar:
  - Higher mass: six grams
**Claim:** Density is dependent on the **Material** not the size or shape of the object.

**Methods:**
- First method: Used formula $L \times W \times H$ to find volume (used a ruler) then measured mass for each
- Second method: Used a graduated cylinder to measure the displacement

**Evidence:**

<table>
<thead>
<tr>
<th></th>
<th>Clay Block (unmold)</th>
<th>Clay Block (mold)</th>
<th>Snowman</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>mass</strong></td>
<td>114.6g</td>
<td>61.9g</td>
<td>52.43g</td>
</tr>
<tr>
<td><strong>volume</strong> (calculated with $L \times W \times H$)</td>
<td>60.275 cm$^3$</td>
<td>35 cm$^3$</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>volume</strong> (calculated with displacement)</td>
<td>65 mL</td>
<td>30 mL</td>
<td>30 mL</td>
</tr>
<tr>
<td><strong>density</strong></td>
<td>1.99 g/mL</td>
<td>1.76 g/mL</td>
<td>1.74 g/mL</td>
</tr>
</tbody>
</table>

**Reasoning:**
- Above evidence shows that the densities do not significantly change when the size of object changes.
- Slight differences are due to methodology and precision of instruments; results equal within a margin of error.
Claim: When the ratio of sodium borate to polyvinyl alcohol changes, there is a change in viscosity in the resulting slime.

Evidence:

Introduction: The lab is intended to observe what happens when two substances are mixed.

- What physical characteristics are observed when a greater ratio/smaller ratio of cross-linking molecule (Sodium Borate) is added to a polymer (polyvinyl alcohol).
- It is important to understand what happens on the molecular level during chemical reactions because this is knowledge that we can apply to new situations we meet in our and fundamentals in order to be able to make advances.
- Macroscopic changes can help us see the attraction between the two substances that we cannot directly view on the molecular level.

Procedure:

We decided to change the ratio relative to the control.

Control: 1:4 ... 5mL Sodium Borate to 20mL polyvinyl alcohol
Test 1 - 1:2 ... 10mL Sodium Borate to 20mL polyvinyl alcohol
Test 2 - 1:8 ... 5mL Sodium Borate to 40mL polyvinyl alcohol

Results:

At first we tested for a change in density.

<table>
<thead>
<tr>
<th>Ratio</th>
<th>1:2 ratio</th>
<th>1:4 ratio</th>
<th>1:8 ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>0.99 g/mL</td>
<td>0.97 g/mL</td>
<td>0.97 g/mL</td>
</tr>
</tbody>
</table>

Table 1: Our test ratios and their densities in g/mL.

- The 1:8 ratio took much longer to dry than the control or test 1:2 ratio trial.

There seems to be no difference in the densities for each trial.

We did however see a change in the physical characteristic of viscosity.

- 1:8 ratio was more viscous than the 1:4 ratio.
- 1:2 ratio was less viscous than the 1:4 ratio.
Figure 15 Bluebird’s poster from iterative inquiry chemistry workshop Poster 4 (Johnstone’s Triangle)
Figure 16 Bluebird’s poster from iterative inquiry chemistry workshop Poster 4 (Elephant’s Toothpaste)
Figure 17 Shaggy’s poster from iterative inquiry chemistry workshop Poster 1 (Soda Challenge)
**Group Fred**

**Density Measurements**

<table>
<thead>
<tr>
<th>Object</th>
<th>Mass (g)</th>
<th>Volume (ml or cm$^3$)</th>
<th>Density (g/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Block</td>
<td>114.5 g</td>
<td>65.625 ml or cm$^3$</td>
<td>1.74 g/ml</td>
</tr>
<tr>
<td>Half Block</td>
<td>58.3 g</td>
<td>32.8 ml or cm$^3$</td>
<td>1.77 g/ml</td>
</tr>
<tr>
<td>Whole Block</td>
<td>114.5 g</td>
<td>65 ml</td>
<td>1.76 g/ml</td>
</tr>
<tr>
<td>Half Block</td>
<td>58.3 g</td>
<td>35 ml</td>
<td>1.67 g/ml</td>
</tr>
</tbody>
</table>

**Method 1 - Measurement**

Error/Uncertainty in Measurements

$$V = L \cdot W \cdot H \pm 0.1 \text{cm}$$

$$m = \pm 0.1 \text{g}$$

**Method 2 - Displacement**

Error/Uncertainty in Measurements

$$V = 25 \text{ ml}$$

$$m = \pm 0.1 \text{g}$$

**Claim:** The more precise the method of measurement the smaller the error.

Figure 18 Shaggy’s poster from iterative inquiry chemistry workshop Poster 2 (Density)
Figure 19 Shaggy’s poster from iterative inquiry chemistry workshop Poster 3 (Slime)
Rubric for Scoring Posters

The posters created during the iterative inquiry chemistry workshop were analyzed to assess the explanations presented as the results of the inquiry activities (see Figure 2-20). A rubric was developed by the research team, derived from several literature sources encompassing effective use of posters for scientific communication (Halonen, 2003) (Matthews, 1990) (MacIntosh-Murray, 2007) (Russell & Good, 2011). The rubric comprised a set of elements that were judged to be most relevant to the Iterative Inquiry Chemistry Workshop, assessing for 17 separate elements that could be present in the posters. The 17 measured elements were placed into three categories that included informational (9 elements), data (5 elements) and conclusive (3 elements), displayed in Table 5 below.
Table 5 Three categories and their assigned elements for rubric

<table>
<thead>
<tr>
<th>Informational</th>
<th>Data</th>
<th>Conclusive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author</td>
<td>Methods</td>
<td>Argumentation</td>
</tr>
<tr>
<td>Title</td>
<td>Materials</td>
<td>Conclusion</td>
</tr>
<tr>
<td>Illustration</td>
<td>Observation</td>
<td>Future Direction</td>
</tr>
<tr>
<td>Introduction</td>
<td>Evidence, Claims, Reasoning</td>
<td></td>
</tr>
<tr>
<td>Citation</td>
<td>Visual Representation</td>
<td></td>
</tr>
<tr>
<td>Significance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purpose</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research Question</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abstract</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6 below displays the rubric designed to score the iterative inquiry chemistry workshop’s posters. The constructed rubric includes five different ranking categories progressing from before training, to emerging, to developing, to proficient, and arriving at skilled. A numeric score was associated with each of the ranking categories. The rankings and numeric scores are as follows, a score of 1 indicates that this element is missing, or it is only minimally present. A score of 2 would be received due to a minimal effort, incomplete, is not clear or is very surface oriented (not integrated well.) A score of 3 indicates that the element is present, but not complete, for instance weak connection between evidence, claim, and reasoning. A score of 4 would be received for being complete and sufficient however missing a small nuance such as credentials for authors, or integrating claim based on evidence and reasoning. A score of 5 indicates scholarship in understanding, including the nuances that provide of full understanding of the element, compelling claim based on evidence and reasoning.

The multiple literature sources were merged together to construct a rubric that focused on three categories thought very important to scientific communication. The rubric was utilized to measure the posters to assess teacher’s progression through the workshop.
Table 6 Poster rubric for assessing the levels of each element of scientific communication, elements are separated into three categories (informational, data, and conclusive) (summarized from complete Rubric in Appendix 1)

<table>
<thead>
<tr>
<th>Components of Informational Elements (Scores Assigned)</th>
<th>Not provided (absent) (1)</th>
<th>Emerging (Basic Understanding) (2)</th>
<th>Developing (Tentative Skills) (3)</th>
<th>Proficient (4)</th>
<th>Skilled (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INFORMATIONAL ELEMENTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Author</td>
<td>No Authors listed</td>
<td>Incomplete list of authors</td>
<td>Authors listed by single name</td>
<td>Authors listed completely</td>
<td>Authors listed with credentials</td>
</tr>
<tr>
<td>Title</td>
<td>No Title available</td>
<td>Title not connected to poster</td>
<td>Title details a portion of poster</td>
<td>Title details experiment</td>
<td>Title creatively captures experiment</td>
</tr>
<tr>
<td>Illustration/ Data sources (Russell &amp; Good, 2011)</td>
<td>Excessive use of text with no illustrations</td>
<td>Minimal use of illustrations</td>
<td>Appealing combination of illustrations and text</td>
<td>Reasonable balance of illustrations and text</td>
<td>Appealing combination of illustrations and text, appropriate font, and color</td>
</tr>
<tr>
<td>Introduction (Matthews, 1990)</td>
<td>Provides unrelated information</td>
<td>Only peripherally related to study</td>
<td>Provides too much information</td>
<td>Provides adequate background</td>
<td>Rationale and significance of research in well-structured logical piece</td>
</tr>
<tr>
<td>Citation/ Reference (Matthews, 1990)</td>
<td>Not provided</td>
<td>Minimal citation</td>
<td>Non APA Citation provided</td>
<td>Citation is there but incomplete</td>
<td>Citation is thorough and includes all information</td>
</tr>
<tr>
<td>Significance / Impact</td>
<td>Not provided</td>
<td>Provided but incomplete</td>
<td>Fails to make a complete argument</td>
<td>States the study’s value OR the problem</td>
<td>Addresses a critical issue; States the value of the study</td>
</tr>
<tr>
<td>Purpose</td>
<td>Not provided</td>
<td>Provided but fail to give a rationale</td>
<td>Scientific investigation lacks scope</td>
<td>Scientific investigation lacks clarity</td>
<td>Scientific investigation succinctly provides the overall picture</td>
</tr>
<tr>
<td>Research Question (Russell &amp; Good, 2011) (MacIntosh-Murray, 2007)</td>
<td>Not provided</td>
<td>Vague unstable research question</td>
<td>Question is testable but broad and unclear</td>
<td>Research Question is testable, narrow, and understandable</td>
<td>Research question is narrow, testable and includes: at least two variables (independent and dependent)</td>
</tr>
<tr>
<td>Abstract</td>
<td>Abstract is not provided</td>
<td>Abstract is not clear</td>
<td>Abstract is clear but incomplete</td>
<td>Abstract is clear, understandable but not succinct</td>
<td>Abstract is clear, understandable, complete, succinct</td>
</tr>
<tr>
<td><strong>DATA DERIVED ELEMENTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methods (Procedure) (Russell &amp; Good, 2011)</td>
<td>Not present</td>
<td>Recites steps in research</td>
<td>Selects and applies method in simple project</td>
<td>Select and apply method to maximize validity</td>
<td>Unique application of research method, builds on primary interest</td>
</tr>
<tr>
<td>Materials used during scientific investigation</td>
<td>Does not identify the materials</td>
<td>Identify only one material/apparatus used</td>
<td>Identify some of the needed materials</td>
<td>Identify most of the appropriate materials used</td>
<td>Identify all needed and appropriate materials used during the investigation</td>
</tr>
<tr>
<td>Observation (Halonen et al. 2003)</td>
<td>Minimally observes behavior</td>
<td>Observes general pattern</td>
<td>Observes holistically</td>
<td>Observes small subtle observations</td>
<td>Sophisticated or detailed observational techniques applied</td>
</tr>
<tr>
<td>Evidence/Claim Reasoning (Halonen et al. 2003)</td>
<td>Lacks evidence, claims or reasoning</td>
<td>In coherent and does not connect evidence, claim and reasoning</td>
<td>Weak evidence, claim and reasoning connection</td>
<td>Integrated claim based on evidence and reasoning</td>
<td>Compelling claim based on evidence and reasoning</td>
</tr>
<tr>
<td><strong>Visual Representation</strong></td>
<td>Not Provided</td>
<td>Minimal representations</td>
<td>Sufficient representation</td>
<td>Sufficient representation that support evidence</td>
<td>Complex representations that support evidence and are referenced in claim;</td>
</tr>
<tr>
<td><strong>CONCLUSIVE ELEMENTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Argumentation Skill (Halonen 2003)</td>
<td>Argues with common sense</td>
<td>Uses basic concepts to develop simple argument</td>
<td>Develops plausible argument</td>
<td>Articulate argument using examples and supports</td>
<td>Complete argument with attention to subtle meaning of content</td>
</tr>
<tr>
<td>Conclusion/ Results (Russell &amp; Good, 2011)</td>
<td>Missing conclusion</td>
<td>Conclusions inconsistent and remotely related to data analysis</td>
<td>Conclusion is partially valid based on the data presented</td>
<td>Conclusion is valid and loosely based on interpreted data</td>
<td>Conclusion is valid and appropriately based on interpreted data</td>
</tr>
<tr>
<td>Discussion and Future direction (Russell &amp; Good, 2011)</td>
<td>Not present</td>
<td>Present but not well framed</td>
<td>Weakly demonstrates synthesis of understanding</td>
<td>Demonstrates synthesis of understanding</td>
<td>Demonstrates synthesis of understanding and framing results</td>
</tr>
</tbody>
</table>

Scoring of the Posters

Table 6 above provides a summary of the levels of each element of scientific communication, a more complete version of the rubric is in Appendix 1. Using the poster rubric, all of the posters were independently evaluated by two researchers (Judge 1 and 2) in order to assign a level (1: not provided to 5, skilled; see Table 6 for each of the 17 elements judged for the three categories (Informational, Data derived, and Conclusive). Both judges, prior to scoring posters, familiarized themselves with the rubric elements and then engaged in discussions aimed at thinking about the elements involved in the rubric. The judges then both independently scored all of the elements in a single poster in order to calibrate their judgments. After the first poster was scored, the judges discussed the poster, and found that all of the element scores matched. The remaining posters were then independently analyzed by both judges. Tabulations of these scores indicated similar agreement for each poster on most of the elements. Notably, it was found that for all of the posters, no one element differed by more than 1 level. The researchers decided to leave these differences, rather than to adjudicate them.

Two examples of poster scoring by both researchers are presented below to illustrate the correlation between the poster and scores for poster elements that were judged. The poster in Figure 21 was created from the first activity by group Sherry, and shows very low levels for most elements. In Figure 22, from activity five, the poster created by Uno were judged to have much higher levels for some of the elements present.
<table>
<thead>
<tr>
<th>Informational</th>
<th>Judge 1 Score</th>
<th>Judge 2 Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Title</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Illustration</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Citation</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Significance</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Purpose</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Research Question</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Abstract</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Data**

<table>
<thead>
<tr>
<th>Data</th>
<th>Judge 1 Score</th>
<th>Judge 2 Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Materials</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Observation</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Evidence, Claims,</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Reasoning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual Representation</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Conclusive**

<table>
<thead>
<tr>
<th>Conclusive</th>
<th>Judge 1 Score</th>
<th>Judge 2 Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argumentation</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Conclusion</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Future Direction</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 21 Designed rubric score for Sherry’s Soda Challenge poster from 2 judges

**Activity 1: Group Sherry.** The majority of the elements (15) received a score of 1 from both judges, indicating that an element was judged at the lowest level for the element (i.e. missing). All of the conclusive elements and all but 1 of each the informational and data categories received a score of 1. We note that this poster was created before the first iteration of community discussion was held about the science in the posters. A score of 2 was received for evidence, claims, and reasoning due to some information on the poster addressing this element (see poster). A score of 3 was received for the element author, which was written in the poster (but redacted here).
Activity 3: Group Sherry. Figure 22 shows the poster for the third activity from group Sherry. The judgments of levels present for the 17 elements are also listed. The poster illustrates that some levels were present at higher levels (3-5). For example, the element research question was explicitly stated in a format that was testable but broad and unclear (level 3). Because the research question was testable, it was judged to be higher than level 2 (2: “vague untestable research question”), but was lower than 4 because it was not narrow and understandable (4: “research question is testable, narrow, and understandable”). Another example is the purpose element that describes the rationale for the experiment. This element was judged at a level higher than 2 (2: “provided but fail to give a rationale”), but lower than 4 (4: scientific investigation lacks clarity”), since the rationale was apparent but lacked scope. The illustration element is the poster’s author use of text, and illustrations used as supporting evidence. This element was judged at a level higher than 4 (4: “reasonable balance of illustrations and text”) and received a level 5 designation (5: “appealing combination of illustrations and text, appropriate font, and color”).
<table>
<thead>
<tr>
<th>Informational</th>
<th>Judge 1 Score</th>
<th>Judge 2 Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Title</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Illustration</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Introduction</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Citation</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Significance</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Purpose</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Research Question</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Abstract</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

| Data                          |               |               |
| Methods                       | 3             | 3             |
| Materials                     | 4             | 4             |
| Observation                   | 1             | 1             |
| Evidence, Claims, Reasoning   | 4             | 4             |
| Visual Representation         | 4             | 4             |

| Conclusive                    |               |               |
| Argumentation                 | 4             | 4             |
| Conclusion                    | 1             | 1             |
| Future Direction              | 1             | 1             |

Figure 22 Designed rubric score for Sherry’s Slime (3rd) poster from 2 judges

Figure 22, scores from Sherry’s third poster illustrates a notable shift when comparing rubric scores from Figure 21, Sherry’s first poster. Both judges score Sherry’s third poster identically with all 17 scores matching. In Figure 22, 10 of the 17 scored elements improved from the score received from the initial poster (score of 1). The citation, significance, abstract, observation, conclusion, and future direction elements continue to receive a 1 on the rubric, and element author remains the same at a score of 3. 10 of the elements show improvement to a level of 3 or 4 on the rubric, with the illustration element improved to a level of 5 (skilled distinction).
The level of 5 is noteworthy, because it represents the top range of this category. It was judged to be a 5 because of appealing combination of illustrations and text, appropriate font, and color.

Focusing on the informational category (e.g. title, introduction, purpose, and research question) increases in the level of poster elements were observed from the first to the third poster. The changes include the incorporation of more of these elements, in a more articulate manner. There was more information provided per each element, the text used was clearer and thoughtful, more concise in conveying meaning and the elements were more connected to the poster. For example for the purpose elements, the scientific investigation is provided and has rationale, and the research question element is testable.

As for the data category, elements showing improvement include the methods, materials, evidence, claims and reasoning, and visual representation. The changes include demonstrating valid methods, identifying appropriate materials, integrating claims based on evidence and reasoning, and sufficient representations to support claims. An example to provide further insight into the changes of claims based on evidence and reasoning is presented below. This excerpt is taken from Sherry’s first poster (see Figure 2).

“Soft drinks with artificial sweeteners are less dense”

The text lacks a connection between the claim; and the evidence.

“All diet soft drinks were more buoyant.”

Reasoning has not been provided, nor any data, or experimental procedure of any type. The poster scores a 1 on the rubric and is categorized as not present (absent) because the words “claim” and “evidence” are used however they are not present.

Poster 3 from group Sherry displays a coherent integrated example of claims and evidence. The following statement is taken verbatim from Sherry’s “Slime” poster.
“We tested different ratios of reactants and found that as we increased the amount of sodium borate the resulting substance got thinner (i.e. had a lower viscosity). We observed this phenomenon while pouring the substances through a funnel and measuring how long it took them to flow through.”

The claim made by the group is connected to the evidence and is supported by reasoning. The rubric score is categorized as proficient “4” due to the integration of claims, evidence and reasoning. A much higher level of sophistication in a very short period of time is evident for this and other data derived elements.

The sole element argumentation in the conclusive category shows improvement. The initial poster receiving a score of 1 indicates argumentation with common sense. A score of 1 would also be received for omitting the element (an example of this is provided above for Sherry’s first poster.) A score of 4 would be received for the argumentation element as participant’s articulate arguments using examples and support. An example of this increase in argumentation skill is observed in the third poster, as the claim is supported by examples, including the data table and the rationale effectively supported in the poster. All of the scores from the posters for each of the two judges are included in the appendix (2).

**Inter Rater Reliability of Poster Assessment**

Inter-rater reliability (IRR) is a means of verifying consistency amongst measurement by different judges. In regard to the posters, two independent judges measured seventeen elements using the rubric. There are a total of 306 scores from each judge and 289 of those scores match. Inter-rater reliability is calculated using the ordinal numbers that are derived from the poster analysis by two coders. Hallgren (2012) in their research effectively applies the inter rater reliability formula below:
\[
K = \frac{P(a) - P(e)}{1 - P(e)}
\]

\( P(a) \) = percentage of agreement (94%)

\( P(e) \) = probability of expected agreement due to chance (42%)

The IRR using a Kappa analysis for the poster is 90%, above the statistically significant threshold of 80% (Hallgren, 2012). Each judge’s scores for the posters are included in the appendix. These scores were used to determine the IRR for the analysis. The highly correlated scoring determines the quality of the designed rubric as well as the consistency of the interpretation of the rubric and assigning the poster an accurate score. No adjustments to the rubric are required to achieve the 94% and the IRR analysis is performed by the author and postdoctoral research associate associated with the Rise Center.

**Summarizing the Poster Results**

The designed rubric measured 17 elements on the posters created during the iterative inquiry chemistry workshop. The poster elements were analyzed with the rubric developed by the research team to determine the elements’ presence and quality. The rubric displayed in Table 6 above is derived from multiple literature sources encompassing effective use of posters for scientific communication (Halonen, 2003). The rubric results for the posters from Sherry are shown in Figure 23 below. Sherry’s work is presented below and is representative of the other groups during the workshop. Similar charts are constructed for the other groups and are in the appendix (8).
Figure 23 Sherry poster rubric scores by element, poster 1 (red, Soda Challenge), poster 2 (green, Density), poster 3 (blue, Slime)

Figure 23 displays 10 scientific communication elements measured with our rubric from posters 1, 2, & 3 created during the iterative inquiry chemistry workshop. Sherry’s posters show significant growth in ten of the elements, displayed in the figure above. The growth is evident when comparing Sherry’s first poster (Soda Challenge) to their third poster (Slime). All seventeen elements are measured with the rubric; however, seven elements displaying minimal growth are omitted. For instance “author”, where participants identify themselves and their
credentials, show limited gains and are omitted. The fourth poster showed minimal gains from
the third and is omitted as well.

A score of “1” (not present) is awarded for nine of the elements on the first poster, and
one element (evidence) scores a “2” (emerging). These scores are indicative of student work
prior to receiving training. The elements receiving a score of “1” are either insufficient, not
observed, or are incoherent. The rubric was used to measure poster 3 (Slime) and scores four of
the elements at a “3” (developing), five of the elements a “4” (proficient), and one element
receives a “5” (skilled) score. The rapid progression on the rubric scale is quite admirable in such
a short duration of time. The scores for the third poster are primarily in the region of proficient
student work, with a skilled distinction awarded for “Sherry’s” illustrations in the slime poster.

The informational category includes elements title, illustration, introduction, purpose, and
research question. They improve over the duration as participants make fewer assumptions about
the communities understanding, and the groups attempt to develop a comprehensive poster to
address these deficiencies. The clarification questions asked during the community discussion
step in iterative workshop cycle facilitate this substantial, quick improvement. Informational
elements, quality improves as a result of the design of the iterative inquiry chemistry workshop.

The data derived category includes methods, materials, evidence, and representation
elements. These elements improve for a variety of reasons, made apparent during the community
discussion step in the iterative cycle. In the initial discussion, participants are asked questions
primarily focused on understanding steps conducted during the experiment and what was used
(methods and materials), so groups can compare their procedures. These questions cease as the
groups add these data derived elements in their posters. The visual representation growth occurs
as the group members learn from each other. They observe effective ways to display the
experimental results through tables, graphs, and figures. The claims based on evidence and reasoning improved as teachers realized that their initial attempts to communicate their claims and evidence were incoherent. This becomes increasing apparent in the community discussions as groups attempt to explain their findings using the text on their poster and realized it is insufficient.

The conclusion category includes the argumentation element. Displayed in Figure 24 below, are two posters (poster 1 and 3) created by group Sherry, their argumentation ability is the focus of this figure.

![Figure 24 Sherry’s poster 1 Soda Challenge (left) and poster 3 Slime (right)](image)

Figure 24 displays posters completed during the iterative inquiry chemistry workshop; on the left is Sherry’s initial poster (Soda Challenge) on the right is Sherry’s third poster (Slime). Argumentation, one of our conclusive elements, measures the ability of teachers to use evidence to substantiate a cohesive defendable claim. Analysis using the designed rubric reveals that Sherry’s claim is incoherent and the supporting evidence is not in agreement for their first poster and receives a score of “1” (argues from common sense). Argumentation progresses quickly and by the third poster (Slime), argumentation moved to a score of “4”, from the insufficient
argument score of a “1” in their first poster (Soda Challenge). The score of 4 is received for an articulate argument with support and examples. Again this rapid improvement is facilitated during the group discussion portion of the iterative cycle. Teachers are made aware through defending their group’s poster that the evidence and claim don’t create an effective argument. The teachers’ self-realization of deficiencies is paramount in their growth. After completing the iterative inquiry chemistry workshop cycle, teachers improve their argumentation skills. The iterative nature of the workshop provides ample opportunity to learn from the participants peers. Peer learning is important aspect, the opportunity to learn from their peers is provided throughout the workshop, however during the group presentation part of the cycle it becomes most apparent.

**Pre and Post Survey**

Teachers completed pre-workshop and post-workshop surveys at the beginning and end of the iterative inquiry chemistry workshop. The surveys, located in the appendix (10), attempt to capture teacher’s understanding of scientific communication, modeling, inquiry, and submicro/macroscopic representation. A portion of the survey was taken with permission from interview questions developed by Dr. Shirly Avargil, a postdoctoral research associate previously working in the RiSE Center.

The pre and post surveys were recorded by participants on paper, tabulated and a grounded theory analysis was conducted (Charmaz, 1995). The grounded theory analysis utilized for this research was similar to the focused coding discussed in the work by Charmaz, which resulted in a set of 10 emergent categories that were used in addressing the survey questions. The categories emerged as a result of analysis of the twenty pre and post workshop surveys. The specific categories emerged as participants either identified the category directly in their
response or the essence of their response was distilled into the category. Twenty pre and post workshop surveys from workshop participants were utilized in the grounded theory analysis, however only the sixteen participants which had filled out both pre and post responses were analyzed. Analysis was conducted in two ways, which are discussed in the following sections. First, was a comparison, pre- to post-, of the presence the identified categories of responses. The second was an analysis, pre- to post-, to examine the depth, quality, and completeness of the different categorical responses.

The Presence of Categorical Responses Pre- to Post- Survey

The survey responses were tabulated to determine the presence of the 10 identified categories present in pre- and post- survey responses. The results of this analysis are included in the appendix (12), (3 teachers missed the pre survey and 1 teacher missed the post) and presented below for the sixteen pairs of surveys having pre and post responses. To tabulate the presence of categories, when a category was identified in a survey response, the category was counted once, until the subject matter changed. Thus, even when a response used a word associated with the category such as “inquiry” multiple times, to articulate a single concept, this would be tabulated as a single entry of that category. A single researcher conducted this analysis, and it involved a focused coding framework to establish a connection between emergent categories and individual survey responses. This allowed identification and expansion of a ‘set” of categories, which evolved as the surveys were analyzed. During the analysis, it was found that the set of categories became largely established after about 20% (i.e. 4-5) of the surveys were reviewed.

To illustrate the process of how categories were created and evolved, here are a series of survey questions and responses.
Survey question: “How would you describe what a scientific model is to someone who is not familiar with models?”

Survey Response: “A model is a representation of a phenomena or relationship which can be used to communicate thinking, clarify ideas, and make predictions.”

This response was first coded under the category “modeling”. Another survey response also was found to be captured by the same “modeling” category:

Survey Response: “A model can be an illustration or device that is used to help someone understand an idea. For example, a model of an atom can be used to show locations of a proton, neutron, and electron.”

Other responses suggested that closely related ideas involving representation could be folded into the category of “modeling”. As the example below illustrates, ideas related to representation can be considered related to modeling. Thus, the category name was changed to representation modeling.

Survey Response: “A scientific model would be a model of something we cannot see with our naked eye. A reference to something we think that it would look like at present time.”

As more surveys were analyzed, the initial categories were examined and some of the category names were modified to capture a broader array of related responses. In the examples above, all three examples were categorized as representation modeling.

Some of the participant’s responses were very elaborate and could be coded in multiple categories. For instance, the response below was coded simultaneously as representation modeling, submicroscopic level understanding, and deeper student thinking.
Survey Response: “Students in middle school have a difficult time with thinking at the micro level because atoms and molecules are so unlike anything they already know. They must also understand charges (+1, -1, 0). The rules in representation, such as with Lewis structure, is unique and takes practice to understand. All of these concepts can be complex, so students shouldn't be given a crash course in any of these concepts. They should be integrated into many of our discussions and activities to build knowledge. It also need to come from their thinking.”

The survey responses analysis and subsequent emergent categories were processed to visually compare the pre-workshop and post-workshop survey differences. The results of this analysis are shown below in Figures 25 and 26.

Figure 25 Three-dimensional plot of the presence of the occurrence of 10 emergent categories per workshop participant measured for the pre survey
Figure 26 Three-dimensional plot of the presence of the occurrence of 10 emergent categories per workshop participant measured for the post survey.

In Figures 25 & 26, 160 different columns are displayed, allowing for a quick overall assessment of the emergent categories. Comparing Figures 25 & 26 (using the same z-scale) indicates that a number of the categories show increases in presence from pre to post survey. An increase in presence, perhaps indicates that respondents are more aware of the emergent categories and are articulating these in their responses to a greater extent than in the pre surveys. This increase in the presence of the categories can suggest that workshop participants had undergone some shift in thinking about these categories. This would be reasonable, if exposure to the workshop design elements has some impact on their post (compared to pre) thinking.

Workshop activities provided participants opportunities to learn about, explore and experience: (1) using representations, (2) the importance of thinking about what was occurring at the atomic scale (submicroscopic thinking), (3) revising models, (4) the limitation of models, (5) using...
evidence to make claims, and (6) communicating and discussion scientific ideas. These concepts were explicitly mentioned in the workshop and are observed in many participant survey responses.

Looking at Figures 25 and 26, although the number of times a category was mentioned appears in many cases to increase, it is somewhat difficult to determine which and to what extent. Also, a few categories appear to decrease, pre- to post but it is also hard to discern details. In order to visualize specific changes per category, Figure 27 was constructed, showing the sum of change by category for each participant between pre and post responses for six categories: representation modeling, submicro level understanding, model revising, communicate science, misconceptions and inquiry. Thus, for each of the sixteen respondents, the sum of pre to post occurrences are graphed categorically. For example, for the category of representational modeling, respondent C has a presence of 1 for the pre survey and a presence of 6 for the post survey resulting in a sum of change of +5 (6-1). For each of the 6 categories, the overall trend is positive and qualitatively matches the changes seen when comparing Figures 25 and 26. Most of the categories also show that several participants had little change. The category of misconceptions showed increases with between 1 and 3 with 7 participants (44 %). The category of inquiry shows a fairly similar pattern. That is, both categories show an increase for about half of the participants. The other four categories generally show broad increases pre to post among the participants. We note that the only category that shows decreases among more than 2 participants is representation modeling. However, this may be explained to some extent by the fact that many of the survey questions directly use the word “modeling”. We analyze in more details the specifics of what the responses encompass in the next section.
Figure 27 Individual categories including (Representation Modeling, Submicro Level Understanding, Communicate Science, Misconceptions and Inquiry) comparison pre to post per respondent

Figure 27 above displays the six categories and displays the difference per workshop participant. While this figure allows us to analyze the impact of the workshop per respondent.
measured pre versus post, another figure was created to assess all of the participant’s responses in aggregate. In Figure 28, below, all of the 16 survey responses pre and post are summed and the differences between the categories are displayed. Figure 28 displays the aggregate presence difference between the pre and post survey responses, i.e. the 16 surveys, pre – minus post, are added for each individual category to determine the sum in each of the 10 categories. An increase in the presence of the surveys indicates the number of survey respondents post than pre.

![Pre-to-Post Changes in Participant Responses](image)

**Figure 28** The difference in presence of the 10 emergent categories pre versus post survey

In Figure 28, there are six categories that show fairly large increases in the number of responses pre-to-post changes. There are four categories that show small changes including limitations of the model, hands on engagement, deeper student thinking, and claims based on evidence. The takeaway from this is though we conducted daily inquiry-based labs, the hands-on component was never explicitly discussed. One possible explanation is that the meaning of
“hands on” became more explicit involving gathering evidence, communicating procedures, describing the analysis, making claims, etc. These will be described further in the next section when the content of what participants discussed is considered in more detail.

The representation modeling, submicro level understanding, model revising, communicate science, misconceptions and inquiry show large gains pre to post. These concepts were explicitly mentioned in the workshop and form many of our ten emergent categories. A reasonable explanation for the increase in presence is that the blend of activities conducted during the workshop that utilized these categories to frame the discussion. In the next section, we will examine if some of these activities were referenced in this way, in the post surveys. Though, misconceptions was not explicitly stated during the workshop design an increase post to pre survey could be attributable to the discussion of student survey data on the second day where student misconceptions were briefly touched on (Student Survey – Implications to Teaching Practices). This will also be examined in the next section.

The increase in presence of mention of most of these categories suggests that workshop participants have adopted succinct language to address challenges faced in inquiry instruction as our survey questions attempt to elicit. This analysis measures the presence of the category; however the quality of the category’s mention is not captured in the table or analysis. The quality of the responses is an important aspect of the surveys and is discussed next.

As suggested above, workshop design elements may have influenced the post survey design elements. These concepts were explicitly mentioned in the workshop and show up in many of participant responses observed in the post surveys. Overall, a reasonable explanation for the increase in presence is that there was a blend of the activities conducted during the workshop that participants incorporated post workshop into their thinking of aspects of science like inquiry
and communication. A quote taken from a post response to a question regarding scientific modeling illustrates the way participants incorporated ideas from the workshop into their thinking:

“Making macroscopic analogies to microscope phenomena is one valuable method to learning chemistry.”

This response indicates the connection between modeling and sub-micro level understanding for this participant that was aided by the blend of activities, one of which was an activity that utilized Johnstone’s triangle. Johnstone’s triangle focuses explicitly on the connection between the submicroscopic, macroscopic and the representation to connect them. Post workshop responses for model revision and communicate science also increased significantly, as a result of the iterative nature of the workshop. Participants had multiple opportunities to practice their scientific communication within their posters in succession. The participants were also made aware of the opportunity to revise their mental models, by opportunities to create more sophisticated ones. Post survey responses for inquiry also shows an increase which may also indicate from a result of the inquiry activities and the explicit nature of the workshop. The increase in presence of mention of these categories suggests that workshop participants have adopted succinct language to address challenges faced in inquiry instruction as our survey questions attempt to elicit.

However, claims based reasoning was a major focal point and was explicitly discussed during each poster session and throughout the workshop and would have been predicted to show larger gains. Though this wasn’t apparent in the survey response data presence measure, it was in the posters. Specifically the evidence and claims based on reasoning portion of the posters, the poster rubric scores displayed large increase
measured from the first to third poster for all groups. This illustrates how utilizing more than one of the data channels (posters, survey, interviews) may help assess the impact of the workshop with participants. This is discussed below in the section on triangulating the data.

**Determining the depth/quality of responses**

In the prior section, the surveys were assessed to compare pre and post responses for changes in the number of responses of categories that emerged using a grounded theory approach. This was analyzed with the thinking that an increase in responses by category might provide clues as to the impact that workshop activities had on participants. For categories such as misconception and communicate science, this will allow us to examine what participants were writing about and if there was any shift in thinking pre-to-post. Other categories, like hands on engagement and deeper student thinking show limited gains. Examining these will also allow us to examine what participants were noting about these categories as well as if there were any shifts in thinking.

**Misconception Category**

The misconception category showed an increase in occurrence pre survey to post. The total number of participants discussing the idea of misconception went from 3 participants out of 16 (20%) to 8 participants out of 16 (50%), a normalized gain of about 40%. In addition, the number of responses in the misconception category went from 3 for the pre survey compared to 12 in the post survey, a 4-fold increase. In order to understand the nature of these changes, we examined how the concept of misconceptions was used. Table 7 shows verbatim pre-responses of participants about misconceptions. These responses indicate some importance to avoidance of
misconceptions, awareness of misconceptions, and how misconceptions can create false ideas.

(see Table 7)

Table 7 Responses from the pre-workshop survey concerning misconceptions

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Question/Response</th>
<th>Misconception use</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Q3. To understand both the purpose of the model to aid in learning and the limitations of each model to avoid formation of misconceptions</td>
<td>Issues pertaining to avoidance</td>
</tr>
<tr>
<td>12</td>
<td>Q6 Having open discussions within the classroom especially group discussions about common misconceptions, giving the students multiple methods for communication chemistry (text/draw/mm representation), lab groups presenting their findings in front of classroom</td>
<td>Awareness</td>
</tr>
<tr>
<td>15</td>
<td>Q2 To make the abstract more concrete for kids. To help kids more or rearrange materials making the molecule seem or appear more &quot;real&quot; weakness - could (and probably does) create false ideas or mistakes in thinking by kids can't go far enough in the process of molecular structure: limited used - models: sometime to kids they do not show the &quot;what ifs&quot; to a concept</td>
<td>Creating false ideas</td>
</tr>
</tbody>
</table>

In the post survey responses about misconceptions, shown in Table 8, we see a dramatic increase in the writings about misconceptions. These comments now shift to the importance of thinking about this issue when teaching, of making students aware about misconceptions, and ideas about strategies to help students minimize and/or avoid misconceptions taking hold in their thinking. This suggests that in pre-survey responses, teachers were indicating the issue of misconceptions in a somewhat more limited and abstract fashion, while post-survey responses have operationalized misconceptions in terms of teaching strategies. Although the word misconception does not appear in any question asked in the pre or post surveys, the dramatic increase in participant response about misconceptions may be directly attributable to the importance that representation and modeling had in the workshop, where workshop discussions related to misconceptions and alternative student conceptions were frequently discussed in terms representation and modeling. Thus, from examining and analyzes the pre- to post- changes in responses of participants, it seems that the participants are much more aware of the importance
of the concept of misconceptions and alternative conceptions, and show more thinking flexibly in terms of framing this critical issue.

Table 8 Responses from the post-workshop survey concerning misconceptions

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Question/Response</th>
<th>Misconception use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Q3. Students need to feel comfortable to take risks and understand that we learn from misconceptions.</td>
<td>Awareness</td>
</tr>
<tr>
<td>2</td>
<td>Q4. A disadvantage is that students can develop misconceptions during this process. For example, bonds between atoms can be viewed as structural not as an attraction.</td>
<td>Issues pertaining to avoidance</td>
</tr>
<tr>
<td>4</td>
<td>Q2. Advantages: generate relation, connectivity, see differentiation, flexibility advantages: scale, misconceptions about bonds, misconceptions of atomic structure.</td>
<td>Awareness</td>
</tr>
<tr>
<td>4</td>
<td>Q3. Students mainly should focus on the primary content the model is conveying and its shortcomings. discussion of said shortcomings are critical to avoid forming misconceptions of material that would otherwise be an excellent model.</td>
<td>Issues pertaining to Avoidance</td>
</tr>
<tr>
<td>7</td>
<td>Q4. Young learners are frustratingly concrete thinkers and many are unable to hold and manipulate abstract ideas about forces and sub-micro objects. Models are hands-on, minds on ways to engage them in this type of thinking. They also may be instructed on strongly-held misconceptions when they can &quot;see what you're saying.&quot;</td>
<td>Awareness Issues Issues pertaining to avoidance</td>
</tr>
<tr>
<td>12</td>
<td>Q2. The purpose is to help create analogues thinking, a way to represent what happening at the microscopic level. Advantages- help students visualize compounds/ molecules bonding a way to represent geometry of molecules. Disadvantages - physical bonds isn't the best way to show bonds creates misconception that bonds are connecting rather than attracting</td>
<td>Issues pertaining to avoidance</td>
</tr>
<tr>
<td>12</td>
<td>Q4. advantages: helps foster the idea that the students ideas are valid, allows them to think long about concepts, gives them the opportunity to communicate with peers (real world science) develop a deeper understanding of the material, doesn't discourage students from sharing ideas, helps with misconceptions disadvantages: lengthy (time-restraints), hard to incorporate into a classroom.</td>
<td>Issues pertaining to avoidance</td>
</tr>
<tr>
<td>14</td>
<td>Q1. A model is a representation (for macro or micro phenomena or relationship) that helps you to create reasoning, communicate, clarify ideas, work out misconceptions, make predictions, ask questions, make claims, and create analogies.</td>
<td>Issues pertaining to Avoidance</td>
</tr>
<tr>
<td>14</td>
<td>Q2. The kits allow students to use their understanding of electrons and bonding to make representations of molecules and reactions. Students can build understanding of what they see happening in the macro world to what is happening at a micro level. Students can then make connections to begin asking questions and leading their own inquiry. The advantages are listed above, but the disadvantage may be in the misconceptions like that atoms are physically bonded, or that the model is always limited in its representation of the real thing.</td>
<td>Issues pertaining to avoidance</td>
</tr>
<tr>
<td>14</td>
<td>Q3. It is important that students can use, develop, revise, and create models. Students should know why a model is used, which means understanding scale and representation. Students should also be able to evaluate a model for its limitations, misconceptions created, and how it represents the real &quot;thing&quot;.</td>
<td>Issues pertaining to Avoidance</td>
</tr>
<tr>
<td>15</td>
<td>Q2. Help show how atomic connect to make molecules. Advantage: &quot;touch&quot; the subatomic world through the model and see a molecule Disadvantage: creates potential misunderstanding about electrons' role in atomic structure. Kids might think the ball is the entire atomic structure nucleus, protons, electrons and neutrons.</td>
<td>Issues pertaining to avoidance</td>
</tr>
<tr>
<td>16</td>
<td>Q8. Looking at student data was good, but wish we could have gone into more common misconceptions</td>
<td>Types</td>
</tr>
</tbody>
</table>
Communicate Science Category

As explained in the previous section, the category of communicate science was mentioned by most teachers in the pre-workshop surveys, but there was a large increase in the number of comments about communication mentioned in post-workshop surveys. To examine what the participants were describing, the pre-workshop and post-workshop surveys responses were examined. Table 9-11 shows selected verbatim responses for pre-surveys, while Tables 12-17 show post-survey responses. Additionally, to capture what participants were discussing about, in terms of the issues related to the process of doing and communicating science, six aspects were coded form in the Tables, shown in the right most columns. These aspects are as follows:

- Group Work/discussions: that involve how students communicate with each other;
- Discuss models: ideas about the science that was are conducting and how this influences the way we communicate (and interpret) science;
- Techniques for communication: related to the issues involved in the techniques of communicating science (e.g. writing, creating Tables, Figures, and posters, etc.);
- Presenting: how to present information and/or its importance in communication;
- Reflection: the process of thinking about science (as it pertains to the influence on communication); and
- Revision: that involves iteration, refinement of models, etc.
Table 9 Pre-workshop survey responses related to communicate science from questions 1, 3, and 4 (group/discussions; discuss models; techniques for communication; presenting; reflection; revision).

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Question</th>
<th>Selected responses</th>
<th>Group Work/Discussion</th>
<th>Discuss models</th>
<th>Techniques for communication</th>
<th>Presenting</th>
<th>Reflection</th>
<th>Revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>1</td>
<td>ideas for promoting deep understanding, collaboration with experienced teachers, use of models in a science classroom, effective demos</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>Communicating to others involves skills</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>Like the idea of &quot;refreshing&quot; what I know and considering ways to better communicate the pertinent info to my students.</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>A scientific model is a way to communicate your knowledge/understanding of a concept so that someone else can learn or understand more about a concept.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>A tool that shows or demonstrates a key concept in science (or other content areas).</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>I would like students to learn how to use a model to show and describe phenomenon. I would also like them to learn how to develop models and discuss their strengths and weaknesses.</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>All Creating their own models. Testing models. Using them to explain a phenomenon rather than to show what something looks like. Collecting data from model (when appropriate). Sharing the model with others and getting feedback on it. Then revisiting it- iterating on it to refine their understanding.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>Modeling- a way to communicate ideas to others a method of demonstrating potential weaknesses in a model when something goes as plan</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>Advantages: promotes conceptual understanding more way of communicating their knowledge/understanding, developing a scientific way of communication (how scientists actually do science.) Disadvantages: most classes are instruction based, how do we incorporate these ideas into the classroom, inquiry learning/teaching is hard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>13</td>
<td>4</td>
<td>Q4. Advantage- refining models allows for higher level thinking, using models makes one more familiar with limitations and purpose, in depth conversations focused on modeling subject disadvantage- time consuming to teach skills, not part of standardized curriculum- what teachers are asked to do</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Table 10 Examining selected pre-workshop responses from question 5 related to aspects related to communicate science (group/discussions; discuss models; techniques for communication; presenting; reflection; revision).

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Question</th>
<th>Selected responses</th>
<th>Group Work/Discussion</th>
<th>Discuss models</th>
<th>Techniques for communication</th>
<th>Presenting</th>
<th>Reflection</th>
<th>Revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>5</td>
<td>Principles that may be used all group activities, hands on manipulatives, and time to share ideas/thoughts</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>The biggest thing is to plan inquiry-based activities around content that can be explained with models on the macroscopic level and then tested in labs. Using peer discussion in some prelab modeling time will allow for a deeper understanding of the content. Careful lesson planning and proper group structure will be essential to the success of any inquiry-based activities.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>Multiple opportunities to connect and discussions to help make connections</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>5</td>
<td>Their needs to be open discussion between students and educators so they can express their thoughts and develop a deeper level of understanding create an environment where students can share ideas, provide activities/labs that require the student to make hypotheses and predictions on their own</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>5</td>
<td>articulate to each other what is happening, drawing, picture, diagrams less scaffolding over time to facilitate true inquiry based activity, teach about inquiry itself self-reflective practice to see individual gains</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>5</td>
<td>Demonstrate/ show concepts multiple ways - use kids sense of wonderment about science, esp. chemistry. Provide information through student interaction what are the pluses and minuses of models- Understand how for a model can or can't go in explaining the abstract What's the difference(s) on how the brain comprehends concrete and abstract concept</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>5</td>
<td>Maybe is students were asked to draw and reflect on a regular basis (almost daily) we would get more in depth thinking. I am hoping using talk science where you expand on other's ideas will help draw out more thought instead of rushing on to answer the lab questions.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Table 11 Examining selected pre-workshop responses from question 6 related to aspects related to communicate science (group/discussions; discuss models; techniques for communication; presenting; reflection; revision).

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Question</th>
<th>Selected responses</th>
<th>Group Work/Discussion</th>
<th>Discuss models</th>
<th>Techniques for communication</th>
<th>Presenting</th>
<th>Reflection</th>
<th>Revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>The groups work is very important, so students can listen and learn from each other. Research shows that students learn from each other and we need to provide them with this opportunity.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>This again ties back to group structure, but also is heavily dependent upon available materials. Communication associated with an inquiry-level activity will only be as strong as the model students are exploring and forming. Activities that are poorly designed will lead to students struggling to align their content knowledge with what the activity calls for. Properly designed activities will make at closer to the statements what needs to be discussed and leaves little room for deviation from the proper path.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>12</td>
<td>6</td>
<td>Having open discussions within the classroom especially group discussions about common misconceptions, giving the students multiple methods for communication chemistry (text/draw/mm representation), lab groups presenting their findings in front of classroom</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>6</td>
<td>drawing, diagram, picture activities to aid in student's ability to communicate, explain verbally to group members of other students, show good examples in order for students to mimic good communication, practice communication skills.</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>6</td>
<td>Role modeling various way to communicate- Kids need to have examples of how to communicate. Provide graphic organizers to help kid’s layout their thoughts. A lot of group interaction provides for a stronger sense of trust for sharing ideas and results of what occurred with their models.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>16</td>
<td>6</td>
<td>I have used &quot;Expo&quot; writeups where students have to communicate what they have discovered in more depth on one topic. These worked somewhat but I need to have more oral discussions where we really consolidate ideas before I ask them to work on a particular question with their group. We also need to talk more about just questions they are &quot;wondering&quot; about.</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>17</td>
<td>6</td>
<td>Helping students to communicate the chemistry they've observed can be done by having them create models of their own.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>intro and summary activities, model good questions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 12 Examining selected post-workshop responses from question 1 related to aspects related to communicate science (group/discussions; discuss models; techniques for communication; presenting; reflection; revision).

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Question</th>
<th>Selected responses</th>
<th>Group Work/Discussion</th>
<th>Discuss models</th>
<th>Techniques for communication</th>
<th>Presenting</th>
<th>Reflection</th>
<th>Revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>The scientific model has changed from the traditional model. Now we need to allow, to help our students learn more, a more inquiry-based model. For example, communication among groups, and whole group questioning what they think they know and how, knowledge by revision.</td>
<td>X X X X X</td>
<td>X X X</td>
<td>X X X</td>
<td>X X X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>A model helps someone understand an idea. For example macroscopic (slime) gives us visual pictures of the attraction between molecules. These physical and chemical representations help someone vocalize their thinking, so other can add or agree upon the understanding (idea).</td>
<td>X X X</td>
<td>X X X</td>
<td>X X</td>
<td>X X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>I would describe it as a representation of something or phenomenon that is hard to explain or see that helps us to explain or visualize it.</td>
<td>X X X X</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>A scientific model is a tangible representation of science concepts, a way to express information concepts and communicate your understanding to a community/audience.</td>
<td>X X X X</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>Model is something that can be used to express micro (unseeable) and macro (seeable). These can be used to explain/challenge phenomenon in the real world</td>
<td>X X X X</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>Q1. A model is a representation (for macro or micro phenomena or relationship) that helps you to create reasoning, communicate, clarify ideas, work out misconceptions, make predictions, ask questions, make claims, and create analogies.</td>
<td>X X X X</td>
<td>X X</td>
<td>X X</td>
<td>X X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 13 Examining selected post-workshop responses from question 3 related to aspects related to communicate science (group/discussions; discuss models; techniques for communication; presenting; reflection; revision).

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Question</th>
<th>Selected responses</th>
<th>Group Work/Discussion</th>
<th>Discuss models</th>
<th>Techniques for communication</th>
<th>Presenting</th>
<th>Reflection</th>
<th>Revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>3</td>
<td>Students mainly should focus on the primary content the model is conveying and its shortcomings. Discussion of said shortcomings are critical to avoid forming misconceptions of material that would otherwise be an excellent model.</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>All… Trying to develop their own models. Trying to turn mental models into physical/visual representations. Testing models. Using them for applied purposes to actually try to explain phenomena. Sharing models. Eliciting and incorporating feedback about their models. And going back and revising their own models to include what new stuff they’ve learned. Also, recognizing the &quot;good&quot; and the &quot;bad&quot; in their own models and others.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>That there are multiple ways to represent or model the phenomena under discussion. Models can be revised it's a way to represent your understanding and communicate it to others macro/micro representations</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>Getting their hands &quot;dirty&quot; and showing their knowledge and how phenomena work, not just reciting the factual knowledge. It helps to &quot;explain&quot; or detail the why it is the way it is. It gives them a chance to &quot;work it&quot; and then ask &quot;what if I&quot; to change variables and see what happens. It gives them the opportunity to expand, question, and engage in the concepts being looked at</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>3</td>
<td>Revision of models, designing/building them, relating them to real life phenomenon discussing them, critically thinking about their strengths and weaknesses</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Table 14 Examining selected post-workshop responses from question 4 related to aspects related to communicate science (group/discussions; discuss models; techniques for communication; presenting; reflection; revision).

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Question</th>
<th>Selected responses</th>
<th>Group Work / Discussion</th>
<th>Discuss models</th>
<th>Techniques for communication</th>
<th>Presenting</th>
<th>Reflection</th>
<th>Revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>Advantages: students expressing what they know or think they know is very important to start with by inquiry based curriculum they can then discuss and question to obtain further knowledge... revisions are important so they can go from where they were with their understanding and progress along the way disadvantages</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Advantages of using, revising, developing models- expands thinking and understanding allows rethinking and revising promotes discussion and communication disadvantages takes time to work through models state does not assess science in this area</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>Q4. advantages: helps foster the idea that the students ideas are valid, allows them to think long about concepts, gives them the opportunity to communicate with peers (real world science) develop a deeper understanding of the material, doesn't discourage students from sharing ideas, helps with misconceptions disadvantages: lengthy (time-restraints), hard to incorporate into a classroom</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>We are getting better at developing models to understand our world, to represent it. What we need to do more is allow students to use it to explain further or associate it to another &quot;issue&quot; and by Revising the model, we allow students to solidify the knowledge and add the new knowledge they learn while communicating their models to others- their &quot;community&quot; Disadvantage to that is it takes time to do it. But, the more we do it the less time it takes since we refine our methods of communication.</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>4</td>
<td>Advantage - models will improve over time (with proper instruction/ feedback) models, when created by groups of students, promote discussion and force students to promote and defend their ideas using knowledge of concepts</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>4</td>
<td>Advantages: Revising models shows that learning in a never ending process. That student’s can learn to change their models as they gain a better understanding of a science principle (or concept). Using models as a spring board for discussion. Disadvantage: Modeling takes a lot of time and time in a classroom is a finite quantity</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Table 15 Examining selected post-workshop responses from question 5 related to aspects related to communicate science (group/discussions; discuss models; techniques for communication; presenting; reflection; revision).

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Question</th>
<th>Selected responses</th>
<th>Group/Discussion</th>
<th>Discuss models</th>
<th>Techniques for communication</th>
<th>Presenting</th>
<th>Reflection</th>
<th>Revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>The triangle connection that we used will be very helpful in facilitating their understanding of science. The communication among students is essential for learning to take place. Equal participation by students will help all learning in the classroom. We also need to allow time for revisions so they can see their growth in the learning process.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>Principles to help students communication skills collaboration willingness to be persistent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>These all ties into the context theme of the weekly work, that being modeling. Open chemistry poster presentations, and synthesis of models/demos are excellent ways of encouraging students to think deeply about what can be observed and what is occurring on the atomic scale in chemistry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>Models! Multimodal representations. Inquiry! Discussions. Lots of exposure. Many hands-on experiences tied to the same concept to allow understanding to develop over time. Pretty much everything I wrote in response to question 3</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>The mere act of involving and engaging students is likely to cause them to keep their attentions focused on the learning. Also, learning in a social activity particularly at their age- they need to Talk to each other and are not good at sustained solo efforts like reading text or waiting.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>Giving multiple ways to represent findings and multiple opportunities to do so - allowing for an ability to gain strength and confidence.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
<td>Again I think group discussions are key</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>13</td>
<td>5</td>
<td>creating models, multimodal presentations, revising their model, more inquiry-based labs, forum for model discussion, posters similar to the ones we made, individuals challenge their models, team work</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>17</td>
<td>5</td>
<td>Facilitate activities that involve these and aspects and promote student discussion and debate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Table 16 Examining selected post-workshop responses from question 6 related to aspects related to communicate science (group/discussions; discuss models; techniques for communication; presenting; reflection; revision).

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Question</th>
<th>Selected responses</th>
<th>Group Work/Discussion</th>
<th>Discuss models</th>
<th>Techniques for communication</th>
<th>Presenting</th>
<th>Reflection</th>
<th>Revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>These ties in with the previous question. Small group work with time for groups to share out w the entire classroom population is very important.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>Models like poster show personal expression of knowledge discussions are used to explain thinking communication increases student's understanding communication builds confidence and respect</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>Inquiry based activities – communication develop activities that teach kids now to be a part of a team with kids disconnected physically (not electronically) They do not know how to interact with live people.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>Allowing them to explore a point of interest … and discussion should be the ideal in promoting communication of chemistry.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>The use of posters was instrumental in helping us to formulate our ideas and communicate those ideas to each other. Using words, tables, graphs, and diagrams allows students to think about what’s happening in a variety of ways. The act of presenting these posters helps students learn how to explain their reasoning to others.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>Poster sessions...Student rubrics where students evaluate other students. Modeling by instructor/peers. Exemplars. &quot;Cheat sheets&quot; of the principles of effective communication. Lots of practice. Small group discussion leading to whole class discussion.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>Again, there is a need for vocabulary so that discussion can happen. They must be able to label objects and events in order to discuss them, and they need time to process and interact with them</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>Communication and being able to successfully share and represent your ideas is a vital part of doing science. You may have made an excellent discovery, but that is only as strong as how well you are able to communicate your findings. I believe posters detailing, claim, evidence and reasoning and having students present their ideas is an excellent way to practice this skill.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>11</td>
<td>6</td>
<td>teach them how to use modeling to successfully understand or relax their knowledge demonstrate proper modeling, use models to discuss concepts demonstrate different modeling for the same concept</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>12</td>
<td>6</td>
<td>Have classroom discussions about these activities, feedback from peers don't give them the answer. Let the students arrive at a answer/decisions on their own posters or some way to communicate these ideas let them be wrong</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>13</td>
<td>6</td>
<td>posters, discussion, community discussions of other posters, multimodal representations, team work talk about thinking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>6</td>
<td>Discussions are critical to developing ideas, revision, and gathering information from others. Making thinking public is important for empowerment and also helping students realize that science is a constant development of ideas, and that it progresses as more thinking occurs.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>6</td>
<td>Ability to revise ideas without making judgements. Practice communicating, having clear rubrics, providing models as guides in helping students in creating their own models or representations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>16</td>
<td>6</td>
<td>Communication can be by posters, oral discussions, drawings, structural models, clickers with discussions, graphing, tables, etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>17</td>
<td>6</td>
<td>Assigning students group activity work that they must present to their classmates and defend their findings and ideas is a great way to help students become successful in communicating chemistry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Table 17 Examining selected post-workshop responses from question 7 related to aspects related to communicate science (group/discussions; discuss models; techniques for communication; presenting; reflection; revision).

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Question</th>
<th>Selected responses</th>
<th>Work/Discussion</th>
<th>Discuss models</th>
<th>Techniques for communication</th>
<th>Presenting</th>
<th>Reflection</th>
<th>Revision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>This week was very important in helping me understand many of the chemistry concepts that I can go back and share with my students. I think the sharing out with all the groups was very beneficial because we were learning from each other. I would like to find out how to get the clickers so I could use them in class.</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>Density, slime lab, and submicro/ macro representation were valuable. Teamwork developed partnership that helped understanding the PSP. Communicate, respect, and community will be taken home. Models show thinking - ideas of success and ones of improvement</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>Honestly, every activity completed in the set chemistry strand contributed positively to the experience of the week. The glue lab was probably the best as it provided inquiry within the groups, practiced the notion of peer-review, and exemplified the micro/macro/ representation triangle at inquiry based science.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>Several diagrams used - Posters, Graphs, Teamwork, Lab Work, Discussion, Tables, and Modeling All of these things I can incorporate into my classroom. Some I already do, but some I could do more of.</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>Teamwork added great value a real sense of community developed over a short period of time comparison of final products(the posters) showed us how much we had grown and developed our skills when I become a teacher I will bring to my classroom the idea of creating a product with multiple modes that effectively communicate our understanding</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>I will refine my use of communicating activities to help students think more of refining editing and using them to deepen their understanding more. I feel I have short-changed them due to time constraints. Reporting out more and reflecting more are my goals for this coming year. I need to get them thinking more.</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>7</td>
<td>all the activities were valuable, the teamwork was enriching, enlightening and successful others collaborative ideas were valuable and enriching, many of the concept/ ideas/ modeling will transfer nicely into the classroom slime is good, models are excellent I still hate posters…even though they are successful in illustrating collaborative work and knowledge</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>13</td>
<td>7</td>
<td>all of them- but for different reasons, I think teamwork was the value- the most important aspect yes into physics classroom as well, poster community pic, inquiry-based lab pic, teamwork pic, model revision pic</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>7</td>
<td>The most valuable activity in the chemistry strand was that we were constantly making posters with which to communicate our findings. This showed us not only how valuable an activity this can Be, but also provided exemplars. Diagram of slippery slime poster</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Pre-workshop survey responses

As shown in Tables 9-11, the pre-workshop participant responses emphasize an appreciation of group work, discussions involving modeling, and the techniques for communication. However, there is relatively little emphasis on presenting scientific findings, student reflection, and revision.

Post-workshop survey responses

As shown in Tables 12-17, part of the increase in teacher responses comes from the now near unanimous appreciation for the importance of group work and discussions involving modeling, with continued appreciate by some teachers in the important of developing different techniques for communication in students. What also emerges is an extensive appreciation for the critical factor that presenting (and discussing it) has on communicating science, as well as the role for reflection and revision in the process of doing and communicating science.

Upon inspection of the depth of each response in the communicate science category there appears to be a significant shift in the “way” it is used as well as the occurrences. For example, in the pre survey teacher 3 states “communicating to others involves skills” a single response in the communicate science category to the question involving inquiry based labs and communication. However, in the post survey the same teacher increases the usage of communicate science to 3 questions including responses “promotes discussion and communication”, increasing students “communication skills” and connecting “Inquiry based activities to communication”. Not only is this teacher citing communicate science in response to a wider variety of questions, they are also connecting activities to communication, promoting more communication in the classroom, and the importance of increasing student communication skills.
The example below is an excerpt from a post survey that emphasizes the importance of presenting scientific findings, student reflection, and revision. This example highlights the difference observed in the post surveys. That is, the importance of communicating science, reflection and revisions in the process of doing and communicating science. These response were coded in three of the categories (presenting, reflecting, and revision) that we see marked improvement measured from pre to post. The presenting aspect is identified in the response “communication among students is essential for learning to take place.” The quote articulates the importance of communication within the classroom. The reflection and revision aspects are intertwined within the following excerpt “need to allow time for revisions so they can see their growth in the learning process.” Thus, this suggests that time needs to be provided to students so that they can reflect and revise their thinking in order to progress in their thinking processes.

**Question:** Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?

**Post Response:**

“The triangle connection that we used will be very helpful in facilitating their understanding of science. The communication among students is essential for learning to take place. Equal participation by students will help all learning in the classroom. We also need to allow time for revisions so they can see their growth in the learning process.”

Another example, show below is a post survey excerpt about the importance of presenting scientific findings, student reflection, and revision. This example highlights a key difference observed in the post surveys (vs. pre-workshop surveys), that is in the importance of communicating science, reflection and revisions in the process of doing and communicating science. This response is coded in the all three of the categories that we see improvement
measured from pre to post (presenting, reflecting, and revision). The presenting aspect is identified in the response “multiple modes that effectively communicate our understanding.” The quote articulately highlights the importance of multiple modes of communication within the classroom. Finally, the reflection and revision aspects are combined in the excerpt “comparison of final products (the posters) showed us how much we had grown and developed our skills” indicating the impact that the workshop had on personal growth, including skill development.

Question: What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking?

Post Response:
“Teamwork added great value a real sense of community developed over a short period of time comparison of final products (the posters) showed us how much we had grown and developed our skills when I became a teacher I will bring to my classroom the idea of creating a product with multiple modes that effectively communicate our understanding.”

Representation Modeling Category

The level of responses for the representation modeling category was very high pre and post-workshop survey, i.e. the total number of teachers discussing representation modeling was 16 out of 16 during the pre-workshop survey and 15 out of 16 for the post survey. In addition, the number of responses in this category showed a modest gain, from 46 to 52. While this indicates a ceiling effect for both in pre-workshop and post-workshop surveys, what is more interesting to note is that there appears to be a shift in the “way” it this category is discussed. For example, in the pre-workshop surveys the majority of the responses describe a model, with comments like “models represent a concept”, “model is a representation of a phenomena”, and “explain an unfamiliar concept/object with an explainable visual aid” show what models can be
used for in comparison. In all of these examples they provide a type of definition. What appears missing is a connection of what the deeper impact of modeling may mean for students.

In the post survey, there appears to be a more robust usage of representation modeling. For example, “The aspects of scientific modeling are giving students the option to express themselves in multiple ways through graphs, table, or other manipulatives. Models can also be used by students to teach their classmates. Scientific modeling can be used to show growth overtime therefore increasing student confidence.” In this response to question 3, “What aspects of scientific modeling are important for your students to learn in your classroom?” the response isn’t wasting any time describing what a model is, but appears concerned with describing the flexibility and student choice in expressing themselves, using the models to help instruct their peers, and build confidence while teaching their classmates. This response highlights a stark difference in the pre-workshop and post-workshop survey responses: that there is a migration from what a model is, or the definition, to what a model can be used for, in the expression of a model, confidence in using, and helping classmates in using a model.

Additional responses in the post-workshop survey shows continued sophistication in thinking in terms of models and representation. Responses to questions include phrases like “developing models- expands thinking and understanding”, and “synthesis of models/demos are excellent ways of encouraging students”. These responses show a change in that no longer are the participants defining models, they are describing the benefits at the student level of implementing models in their instruction.

**Submicro Level Understanding Category**

The submicro level understanding category showed an increase in occurrence measured from pre-to-post-workshop surveys. The total number of teachers discussing submicroscopic
level understanding went from 7 out of 16 (44%) during the pre-workshop survey to 14 out of 16 (88%) for the post-workshop survey, a normalized gain of about 80%. In addition, the number of responses significantly increased from 12 to 31 responses, an increase over 150%. In examination of the responses for what was being written about, we find a significant shift taken place pre- to post-in the “way” that the idea of the submicroscopic was used.

In the pre-workshop surveys, the responses show minimal evidence in support of participants thinking in submicroscopic terms. The majority of the responses appear to be somewhat abstract, using phrases such as “impossible to visualize”, “can’t be seen” and “atoms join together”. There were very limited instances (3 out of 12) using words that discuss submicroscopic phenomena, i.e. only a few responses describing: “sub-microscopic level”, “atomic scale”, or “molecular level” in any sort of sophisticated way. Also, over half of the responses were limited to responses having to do with question 2, which asked about the use of a model kit:

“In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?”

The post survey response used a much wider range of ideas describing the submicroscopic level, including phrases like “representation (for macro or micro phenomena)” and “visualize the micro world”, and expressing more sophisticated connections between the submicroscopic levels. The types of vague references that appear in the pre-workshop surveys also were greatly diminished. Additionally, in the post responses two other interesting items appear: the responses (1) use a more active voice and (2) relate the connection between domains more explicitly, i.e. macro to micro or submicro to macro. A sample of examples include:
“Drawings at sub atomic level to explain macro” and “using the triangle model of representation, observation (macro) and submicro helps kids make connections and to ask more questions”. These responses make evident a more active voice for integrating submicroscopic level understanding and connect them to the positive impact on students. In 8 of the 32 of post-workshop surveys), the submicroscopic level understanding described in the article by Johnstone (Johnstone,1993) (i.e. Johnstone’s triangle) is specifically referenced, providing evidence of the impact that this reading assignment, poster, and discussion had on some participants.

**Limitations of Models Category**

The limitations of the modeling category showed little change in occurrence as measured from the pre-to-post workshop surveys. The total number of teachers discussing limitations of models went from pre: 15 out of 16 (94%) to post: 16 out of 16 (100%). In addition, the number of responses in this category remained unchanged: 23 for the pre and post survey. Though this would indicate no change as a result of the PD through a quantitative measurement instrument, a qualitative analysis determining what participants discuss in terms of models limitations was analyzed.

In the pre-workshop surveys, the responses describe specific limitation of a model similar to the one suggested in question 2, (i.e. about modeling kits). Typical responses in the pre-workshop survey include “color may be confusing”, “doesn't show what kind of bond, or number of electrons” and “very difficult for students to move from a chemical equation from letters and numbers to a visualization of the molecular process taking place.” These comments describe specific aspect of models shortcomings and do not refer to the abstract nature of the limitations of models. This is apparent in Figure 31 below (response on left), displaying a teachers pre survey response in a very concrete way.
<table>
<thead>
<tr>
<th>Pre Survey Response</th>
<th>Post Survey Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Question #2</strong></td>
<td><strong>Question #2</strong></td>
</tr>
<tr>
<td>In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?</td>
<td>In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?</td>
</tr>
</tbody>
</table>

Response:

“....learn how other molecules bond together. The disadvantages are that they don’t perfectly represent the real thing.”

Disadvantage

“....that the model is always limited in its representation of the real thing.”

**Figure 31: Excerpt for Teacher 14 from Pre and post survey instrument.**

In the figure the question extracted from each of the surveys is displayed at the top and the pre response is on the bottom left and the post response on the bottom right. The response in the pre survey “the disadvantages is that they (model kit) don’t perfectly represent the real thing.” The participant addresses the limitation of this specific model, the model kit. The teacher referred to the model kit’s limitation that it doesn’t perfectly represent bonding of atoms. However, in the post response the same participant now identifies a disadvantage of the model kit by stating “the model is always limited in its representation of the real thing.” This teacher was abstractly describing shortcomings of all models and the necessity to having multiple models to represent the macro world phenomena. A shift in thinking was apparent, pre- to post-workshop for this teacher, in that they are identifying all models have limitations.

**Model Revising Category**

The model revising category showed an increase in occurrence as measured from the pre survey to post. The total number of teachers discussing model revision went from 10 out of 16 (63%) in the pre survey to 14 out of 16 (88%) for the post survey. That’s a normalized gain of
about 67%. In addition, the number of responses in this category was pre: 16 to post: 26. The model revising understanding category displayed an increase of occurrence of 63%.

Obviously, this data reveals occurrence but not what type of responses were made. Analysis revealed a shift in the “way” that the concept of revision was used. For example, in the pre survey, half (8 of the 16) of the pre survey responses were about question 4, which asked about reflection on what advantages and disadvantages there are about the NGSS recommendations that students should engage in developing, using and revising models. This response was typical: “The advantages for developing, using and revising models are students become vested in their own learning.” This is a simple restatement of the question and is very vague. This example and other similar responses, stresses the advantage of students revising models for their own learning. Specifics about how to accomplish creating this are omitted. In another example, “refining models allows for higher level thinking” the response is again vague.

In contrast, in the post survey responses, the same question (#4) elicited significantly different and more detailed responses, such as “Advantages: Revising models shows that learning in a never ending process, that students can learn to change their models as they gain a better understanding of a science principle (or concept). Using models as a spring board for discussion”. This response indicates a process of continuous model revision that is directly connected to discussion, with a goal of developing insight into scientific concepts. The idea that sharing your views through discussion, connects communication to the process of developing conceptual path of understanding, and aligns with the learning outcomes put forth for the iterative inquiry workshop. In another example, we see what appears to be a shift in a teacher’s thinking: “We are getting better at developing models to understand our world, to represent it. What we need to do more is allow students to use it to explain further or associate it to another
"issue" and by revising the model, we allow students to solidify the knowledge and add the new knowledge they learn while communicating their models to others- their "community". This is another example of the migration to a more sophisticated understanding of model revision, and emphasizes a role of the teacher in facilitating discussion among students, i.e. the community in order to help students solidify knowledge and extend it.

In response to other questions, we also see similar shifts. For example, in Figure 32 is shown the pre- and post-survey response of a teacher from question #6. In the pre-survey, we see the principles of providing multiple opportunities to make connections, without providing further details. However, the post response, suggests that this can be part of a strategy for gaining strength and confidence, to “see” or “illuminate” connections, reinforce ideas from the “community of thinkers” in order to think further (e.g. at a deeper level). While the pre-response sets a goal, the post-survey response in much richer in describing how communication can lead to student conceptual change and increased levels of confidence.

<table>
<thead>
<tr>
<th>Question: Sometimes we want to facilitate inquiry-based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Response:</td>
</tr>
<tr>
<td>“Multiple opportunities to connect and discussions to help make connections”</td>
</tr>
<tr>
<td>Post Response:</td>
</tr>
<tr>
<td>“Giving multiple ways to represent findings and multiple opportunities to do so - allowing for an ability to gain strength and confidence. Reconnecting to previous activities to see or illuminate connections made. Reinforcing a community of thinkers to be able to promoting. Gain confidence to think further and want to think further.”</td>
</tr>
</tbody>
</table>

Figure 32 Pre and post survey excerpt from a workshop participant (above is the question, middle is the pre survey, bottom is the post survey)
In summary, the pre workshop surveys included less details about how scientific communication could be used as a strategy, while the post-survey responses show a shift where the appreciation of scientific communication as a strategy for helping students learn science came up multiple times. We note that a majority of teachers exhibited this shift, this was not observed for a minority of teachers. To provide a new addition examples of this shift in thinking, is a post survey response shown below:

> “Discussions are critical to developing ideas, revision, and gathering information from others. Making thinking public is important for empowerment and also helping students realize that science is a constant development of ideas, and that it progresses as more thinking occurs.”

Finally, we saw some changes in teachers’ understanding of using evidence and reasoning to support claims. Figure 33, below displays the question and pre and post response. The question asks teachers about the principles of communicating chemistry. The pre survey response is a verbose laundry list of big picture concepts that are important. The succinct post survey response identifies specific steps that could be used to reach the goal of effectively communicating science through claims, providing both evidence and reasoning. The post survey response specifically states “Ensuring that students are doing the work of creating explanations through claims, providing evidence, and reasoning.” The second part of this statement, “These concepts need to be discussed, ideas revised, and models developed to allow for deeper thinking.” suggests influence of the iterative inquiry chemistry workshop model.
Question: Sometimes we want to facilitate inquiry-based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?

Pre Response:
“Ensure that all students can feel successful with some part of the inquiring process. Not all students will reach the higher level, deeper thinking in the time that is given. Students will need several opportunities to explore. Differentiation is important to challenge all students. Lots of opportunities to speak to one another, draw their ideas, plan responses, revise ideas, and make their thinking public. This process cannot be rushed.”

Post Response:
“Ensuring that students are doing the work of creating explanations through claims, providing evidence, and reasoning. These concepts need to be discussed, ideas revised, and models developed to allow for deeper thinking.”

Figure 33 Pre and post survey excerpt from a workshop participant (above is the question, middle is the pre survey, bottom is the post survey)

Interviews

Seven teacher interviews were conducted within a month of the iterative inquiry chemistry workshop using a scripted protocol, located in the appendix (5). During the 1 month interview, teachers were asked open ended questions about the developments in their posters. To facilitate the interview, the posters were displayed in order for the teacher’s to make visual comparisons. Two additional interviews were conducted 18 months after the workshop located in the appendix (6). The interviews were qualitatively assessed to capture teacher’s changes in terms of strategies and techniques learned during the workshop. Additionally, the interviews attempt to determine the persistence of the workshop experience. The interviews were transcribed and a grounded theory analysis was conducted. The interviews were analyzed in two ways, first to determine the presence of emergent categories in their responses and second to analysis of the type and content of the responses (e.g. depth and quality).
The presence of emergent categories was the first step in the analysis and was conducted by a single researcher. The grounded theory analysis approach was similar to the focused coding discussed in the work by Charmaz. The focused coding framework establishes a connection between emergent categories and individual responses. The responses vary in length but essentially are between one sentence and a paragraph. An example of a response is shown below:

“each time we completed a poster we put it on display and kind of went over it orally and said what are findings were, whether they were what we expected or not.”

This response was coded in the category of communicate science as they were elaborating on the communication aspect of science in the workshop. Some of the participant’s responses were very elaborate and could be coded in multiple categories. Thirteen categories arose from the grounded theory analysis.
Table 18 Frequency of categories, present in post-workshop interview

<table>
<thead>
<tr>
<th>Categories</th>
<th>Representation</th>
<th>Modeling</th>
<th>Submicro level understanding</th>
<th>Communicate Science</th>
<th>Claims Based on Evidence</th>
<th>Group Influence</th>
<th>More Sophisticated Poster</th>
<th>Learner Role</th>
<th>Limitation of Models</th>
<th>Model Revising</th>
<th>Hands on Engagement</th>
<th>Deeper Student Thinking</th>
<th>Misconceptions</th>
<th>Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interview 1</td>
<td>2</td>
<td>2</td>
<td>7</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<tr>
<td>Interview 2</td>
<td>4</td>
<td>1</td>
<td>7</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>0</td>
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<tr>
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<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
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<tr>
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<td>2</td>
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<tr>
<td>Interview 5</td>
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<td>5</td>
<td>2</td>
<td>3</td>
<td>3</td>
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<tr>
<td>Interview 6</td>
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<td>2</td>
<td>1</td>
<td>3</td>
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<td>1</td>
<td>0</td>
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<tr>
<td>Interview 7</td>
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<td>3</td>
<td>2</td>
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</tr>
<tr>
<td>Interview 8 &amp; 9 (18 month)</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
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</tbody>
</table>

below displays the presence of the thirteen categories mentioned in the interview.

Two groups of interviews were conducted: (1) individual participants were interviewed approximately 1 month after the conclusion of the workshop (1-7), while two of the participants were interviewed by phone simultaneously after approximately 18 months (8 and 9). The purpose of the interviews was to help inform our research questions.
Upon analysis of the interviews, there were 13 categories that emerged (see Table 18), with 7 categories being mentioned in nearly every interview (by some multiple times), while 8 categories were much less mentioned.

During the workshop, Johnstone’s triangle was the subject of an activity (with poster), and the findings in this paper were frequently referred to and discussed by participants in the latter half of the workshop. Johnstone’s triangle focused explicitly on the connection between the submicroscopic, macroscopic and the representation to connect them. The large number of references to categories related to describing the major theme in the Johnstone paper, i.e. formulating representation, appears to be responsible for the large number of references in the interviews to the categories of representation modeling and submicro level understanding. In

Table 18 Frequency of categories, present in post-workshop interview

<table>
<thead>
<tr>
<th>Categories</th>
<th>Representation Modeling</th>
<th>Modeling Submicro level understanding</th>
<th>Communicate Science Claims Based on Evidence</th>
<th>Group Influence</th>
<th>More Sophisticated Poster</th>
<th>Learner Role</th>
<th>Limitation of Models</th>
<th>Model Revising</th>
<th>Hands on Engagement</th>
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<tr>
<td>Interview 2</td>
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<tr>
<td>Interview 3</td>
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<td>1</td>
<td>3</td>
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<tr>
<td>Interview 4</td>
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<td>Interview 5</td>
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<td>Interview 6</td>
<td>7</td>
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<tr>
<td>Interview 7</td>
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<td>3</td>
<td>2</td>
<td>5</td>
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<tr>
<td>Interview 8 &amp; 9</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>4</td>
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</tr>
</tbody>
</table>

Interview 8 & 9 (18 month)
fact, about 25% of all of the teacher responses appear related to these two categories (29/160; see Table 18).

The communicate science category also shows a significant number of responses, perhaps as a result of the iterative nature of the workshop. Participants had multiple opportunities to practice their scientific communication within their posters in succession. Claims based on evidence shows an increase; this is attributed to the group discussion step within the iterative cycle and having to substantiate claims that were made.

The analysis shown in Table 18, measures the frequency within different categories. We also examined the details of these categories. i.e. the specifics of what teachers were saying in the interviews concerning these categories. During the interview, many workshop participants characterized the differences they observe in the posters and describe their thinking about the rationale for the differences. An excerpt of one of the responses to the open-ended question taken from the interview is displayed below. This quote captures a common theme expressed by the teachers, that is, that the iterative process of the workshop contributed directly to the improvement in the quality of scientific communication, captured by their posters. Teachers noted that their posters developed as a response to the iterative processes that continued throughout the workshop. The quote below is an excerpt from a short term – 1 month interview.

“I think what happened is, as time went on people looked at them [the posters] and they [the posters] just got more detailed because the discussion got richer and as the discussion got richer then I think the information that got to the posters became richer...as people were presenting you were noticing what other people were doing...and then everybody was trying to make theirs better.”
As previously stated, participants were interviewed 1 month after the conclusion of the iterative inquiry chemistry workshop. These interviews were analyzed for evidence addressing teachers’ understandings of using evidence and reasoning to support claims. As one teacher stated in the interview,

“As the week went on, I believe we became more cognizant of how to set up questions and provide the evidence and make a claim.”

This interview excerpt highlights the importance of the chemistry workshop’s iterative nature. The repetitive cycling of the activities conducted facilitates teacher’s understanding of “how” to create research questions, and provide evidence and claims. The quote also indicates instructors’ self-awareness of the repetitive nature, and that they ascribe this as being critical to better understanding about how to use evidence and reasoning to support claims.

The interview also provides the teacher an opportunity to reflect on the iterative inquiry chemistry workshop’s impact. The interview process involved displaying the posters to the interviewee, and thus initiated teacher’s self-reflection. The interview created an opportunity to reflect on “why” the posters became better. As one teacher stated during a follow-up interview, one month after receiving the training:

“Reasoning is obviously missing from our first poster and we spent a lot of time discussing reasoning…I think through the discussions of the reasoning, I think that we could better decide what finding(s) to put on our poster…”

The stark contrast between the first and third poster as displayed in Figure 24, becomes apparent for many teachers being interviewed. The posters being displayed were critical in getting participants to observe progression of inquiry over the course of the workshop, and crystallized how iterating inquiry could be used to deepen scientific thinking.
The long term interviews conducted 18 months after the iterative inquiry chemistry workshop were conducted to assess some of the impact on teaching practices. Two teachers were simultaneously interviewed through Skype, each being in a separate location. The interview protocol, attached in the appendix (6), “Teacher Interview Protocol - 18 months after iterative inquiry chemistry workshop” attempts to elicit the overall impact of the workshop. Below in Figure 34, Amy and Bart, two workshop participants, respond to an interview question. These are both pseudonyms used to protect the identity of the participating teachers. This is aligned with the IRB process, in order to properly handle data in terms of privacy and archiving.

Amy’s response to the open-ended question focuses on claims based reasoning from evidence. For Amy, the iterative inquiry chemistry workshop impact has been persistent in that she recalls the workshop and is utilizing the claims-based reasoning training she received 18 months prior. Amy chooses to make the focal point of the workshop’s impact on discussion of claims-based reasoning as it is important to her. Amy also mention’s various applications of claims- based reasoning beyond the scope of chemistry classes. Finally, she explicitly states her role as a student during the iterative inquiry chemistry workshop is a key tenet of an effective workshop. Lasting beneficial change is fostered by a student type role.

Bart’s agrees with Amy’s comments and goes on to elaborate on his experience from the poster presentations and the explicit nature of the workshop. Bart elaborates on his increasing explicitness in the classroom in discussing claims based reasoning, as well as his expectations of the students as a result of his experience. The iterative procedure implemented during iterative inquiry chemistry workshop is replicated in his classroom for his students to share the experience. Bart allows students to reflect upon their work in order for them to refine their claim
based reasoning. Bart desires to impact his students similarly, using the iterative model, the goal being to have his students use evidence effectively to substantiate an argumentation.

**Question: Did the summer academy impact you as an instructor? The responses were sequential.**

**Amy’s Response:**

“I would say yes because what you did is you modeled the claim evidence and results model and I took that back and that is exactly what we are doing in our classes at least I’m doing in my class. It didn’t have to be just Chemistry, it transferred to all classes that I was doing. So, being able to walk through that as a student helped me realize the parts of it that might be more difficult than others, also might have doubly helped me in the progression....”

**Bart’s Response:**

“I would echo everything that Amy said it definitely impacted me; it definitely had me focus on the claim, evidence and reasoning and how I would present it and how I would talk about it. The one thing that I would add is that the whole experience of doing it through the model of poster presentations really impacted me. It made me up my game in expectations for students and how explicitly I taught things. I actually replicated in that I asked for a poster and had them produce such squalid crap and then broke it down and we looked at it compared to real posters and we looked at different parts of them. Many of them had the same experience that I did, where they were embarrassed....”

Figure 34 Excerpt from Teacher Interview Protocol - 18 months after iterative inquiry chemistry workshop (Top- question, Middle - Amy’s response, Bottom - Bart’s response)

In summary, for the 1 month interviews, teachers indicated that the workshop had a significant influence on their understanding of scientific inquiry, and at the 18 month interview, the two teachers who participated; both indicated a long term influence of the workshop on their teaching practices

**What Does Our Data Reveal?**

To examine the effectiveness of the teacher PD in the 2014 Iterative Inquiry Chemistry Workshop, we asked three major questions related to the effects of iterating inquiry activities:
1. What was the effect of the professional development on teacher’s scientific communication skills?

2. In what ways did the professional development affect the use of evidence and reasoning in supporting claims?

3. What was the effect of the professional development on teacher’s understanding of inquiry?

After analysis of data, three assertions appear to be supported:

**Assertion 1 Summary: Workshop participants increased their scientific communication and gained practical skills in scientific communication**

Assertion 1, that workshop participants increased their scientific communication and gained practical skills in scientific communication was substantiated through evidence from the posters, pre- and post-workshop surveys and interviews. In the results and discussion section above, Figure 23 displays 10 scientific communication elements measured with our rubric from posters 1, 2, & 3 created during the iterative inquiry chemistry workshop. An improvement is evident, substantiated by the apparent increase of scores received for groups scientifically communicating through their posters. The communicate science category show large gains pre-to post-workshop, per Figure 28, in comparing the category’s occurrence. In Tables 9-17, an analysis of pre and post survey data provides an opportunity to inspect the depth of each response in the communicate science category. There appears to be a significant shift in the “way” that communication is used. This shift is captured in numerous post-workshop survey responses, where the importance of communicating science, reflection and revisions in the process of doing and communicating science is stated. For the interview data, Table 18 displays
the categories per interviewee and the occurrence of each category. Scientific communication (29 instances) was one of the three highest occurring categories along with representation modeling and group influence. The following excerpt from an interview captures a common theme expressed by the teachers: “the iterative process of the workshop contributed directly to the improvement in the quality of scientific communication, captured by their posters”. Scientific communication skills are critically important for teachers to understand and the workshop participants have improved these skills.

Assertion 2 Summary: Teachers’ understandings of using evidence and reasoning to support claims improved during iterative inquiry chemistry workshop

Assertion 2, that the teachers’ understandings of using evidence and reasoning to support claims improved during the iterative inquiry chemistry workshop was substantiated through evidence from the posters, pre- and post-workshop surveys and interviews. In the results and discussion section above, Figure 24 displays posters completed during the iterative inquiry chemistry workshop; including Sherry’s initial and final poster. Argumentation, one of our conclusive elements, measures the ability of teachers to use evidence to substantiate a cohesive defendable claim. In their first poster a score of “1” is received, however argumentation progresses quickly and by the third poster (Slime), argumentation moved to a score of “4”. This significant improvement appears to be facilitated during the group discussion portion of the iterative cycle. Teachers are made aware through defending their group’s poster that the evidence and claim by themselves, don’t create an effective argument. The claims based on evidence category show gains in comparing the category’s occurrence from pre- to post-workshop, displayed in Figure 28. The following excerpt from the post survey captures a common theme
expressed by the teachers, “‘working on what a claim is from evidence and how you can support it with scientific reasoning. My students are still not good at this.” For the interview data, Table 18 displays the categories per interviewee and the occurrence of each category. Claims based on evidence was an average occurring category (17 instances) along with submicro level understanding and more sophisticated poster. The following excerpt from an interview captures a common theme expressed by the teachers, “As the week went on, I believe we became more cognizant of how to set up questions and provide the evidence and make a claim.” This interview excerpt highlights the importance of the chemistry workshop’s iterative nature. The repetitive cycling of the activities conducted facilitates teacher’s deep understanding of “how” to create research questions, and provide evidence and claims. Argumentation skills are important for teachers and the workshop participants have improved these skills.

**Assertion 3 Summary: The iterative nature of the iterative inquiry chemistry workshop facilitates an increase in teacher’s inquiry understanding**

Assertion 3, that the iterative nature of the iterative inquiry chemistry workshop facilitates an increase in teacher’s inquiry understanding was substantiated through evidence from the posters, pre- and post-workshop surveys and interviews. Figure 23 displays 10 scientific communication elements measured with our rubric from posters 1, 2, & 3 created during the iterative inquiry chemistry workshop. Sherry’s posters show significant growth in ten of the elements, in Figure 23. These elements form the basis of the fundamentals of inquiry. The understanding and proficient use of these elements demonstrate an increase in inquiry understanding. The surveys attempt to capture teacher’s understanding of inquiry, in addition to scientific communication aspects. Figure 28 displays the aggregate presence difference between
the pre- and post-workshop survey responses, i.e. the 16 surveys, pre – minus post, are added for each individual category to determine the sum in each of the 10 categories. An increase in the presence of the surveys indicates the number of survey respondents post than pre. Inquiry displays the fourth largest increase (12) over the survey comparison. The following excerpt from the post survey captures a common theme expressed by the teachers “Advantages: students expressing what they know or think they know is very important to start with by inquiry based curriculum they can then discuss and question to obtain further knowledge...revisions are important so they can go from where they were with their understanding and progress along the way disadvantages” For the interview data, Table 18 displays the categories per interviewee and the occurrence of each category. Inquiry was a less frequently occurring category (3 instances). The following excerpt from an interview captures an important theme expressed by the teachers, “But to have that type of experience helped me to reflect on what I was doing in my classroom and am I allowing them to be creative and giving them kind of an open question that they can explore.” This interview excerpt highlights the importance of the chemistry workshop’s iterative nature and its applicability to the classroom. The inquiry component is a key point in the response, evident in the use of “creative” and “open question they can explore.” Both of these are critical to the inquiry model. A better understanding of the nature of inquiry is imperative for teachers and the workshop participants have improved these skills.
CHAPTER 6

CONCLUSION
Summary of Findings

The National Science Teachers Association recommends that all science teachers use instructional practices that support scientific inquiry, in alignment with Next Generation Science Standards that integrate content with inquiry practices (NGSS, 2013). However, research has shown that many science teachers do not have robust understandings and experiences of scientific inquiry (Capps & Crawford, 2013) or may not manifest it successfully in their classroom practices (Bartos & Lederman, 2014; DiBiase & McDonald, 2015). This study investigates teachers’ learning of inquiry elements including scientific communication skills and evidence and reasoning to support claims, through participation in an iterative inquiry-based chemistry workshop. The following set of research questions are asked after our workshop.

1. What was the effect of the professional development on teacher’s scientific communication skills?

2. In what ways did the professional development affect the use of evidence and reasoning in supporting claims?

3. What was the effect of the professional development on teacher’s understanding of inquiry?

A professional development experience embedding components of effective PD and an iterative model facilitated more robust scientific communication ability; claims based reasoning understanding, and inquiry understanding. We advanced a model of PD – whose activities included iterative inquiry activities. The model includes opportunities to engage in inquiry activities in succession over a short span of time. The apprentice model provides opportunities to practice skills including scientific communication, argumentation, and inquiry. This was
explicitly designed into many of the PD activities involved in this workshop. Scientific communication, argumentation, and inquiry skills were iterated in order for reinforcement. This was a critical aspect of the PD design in order to deepen participant’s inquiry understanding. Our data (Poster, pre-workshop to post-workshop surveys, interviews) suggests that this PD model significantly benefited the participants. The findings of the study include scientific communication elements showing significant growth from group’s first poster to their third poster. For the survey data, the communicate science category show large gains in the category’s occurrence measured pre to post survey. Additionally in the survey data, there appears to be a significant shift in the “way” the communicate science concept is used. This shift is stated in numerous post survey responses, where the importance of communicating science, reflection and revisions in the process of doing and communicating science. For the interview data, scientific communication was one of the highest occurring categories mentioned.

The study’s findings include argumentation, one of our conclusive elements which measure the ability of teachers to use evidence to substantiate a cohesive defendable claim. A significant improvement was observed, measured from the participant’s first poster to the last. This growth appears to be facilitated by group discussions that were iteratively cycled, allowing teachers to become aware of how their claims rested on the data and reasoning. For the survey data, the claims based on evidence category show gains in the number of responses but also a shift in how teachers thought about constructing arguments. The interview data indicated a heighten appreciation by teachers of how claims are constructed from a foundation of data and analysis.

The findings of the study include elements of inquiry understanding as displayed in the poster figures. Increased scores from the participant’s initial posters to their final posters, suggest
an increase in inquiry understanding, through their proficient use. The pre- post-workshop survey questions attempted to capture teacher’s understanding of inquiry. An increase in the presence of the category indicated a higher occurrence of survey response measured in the post than pre. The following excerpt from the post survey captures a common theme expressed by the teachers “Advantages: students expressing what they know or think they know is very important to start with by inquiry based curriculum they can then discuss and question to obtain further knowledge...revisions are important so they can go from where they were with their understanding and progress along the way disadvantages” For the interview data, inquiry was measured as a category discussed in the interviews. The following excerpt from an interview captures an important theme expressed by the teachers: “But to have that type of experience helped me to reflect on what I was doing in my classroom and am I allowing them to be creative and giving them kind of an open question that they can explore.” This interview excerpt highlights the inquiry component is a key point in the response, evident in the use of “creative” and “open question they can explore.”

The data suggests that the iterative inquiry activities are a significant reason for the pre-to post-workshop changes we observed. The areas of scientific communication, claims based on evidence and reasoning, and inquiry appear to be significantly impacted while some areas appear less impacted: abstract, citation, and future direction (rubric elements). We note that these less impacted areas were not the focal point of our professional development model.

The goal of any professional development is to affect workshop participants and impart change on their classroom instruction. The long term interviews indicate that the workshop had significant impact of these teachers (although they are a small sample size). Their self-reported changes on classroom practices, an NGSS goal, are especially noteworthy.
In addition to developing their own skills and practices during scientific investigations, the teachers reflect insightfully on implications for their classroom practices. As one teacher stated in the post-workshop survey,

“I found all [workshop] activities beneficial…questions with discussion and working with our group to develop reasoning. We were interested in developing reasoning because it was interesting, fun and had value, I need to bring more of that feeling to my classroom.”

This study provides specific evidence of increasing teachers’ understandings of and skills in inquiry practices, both for themselves and in thinking about their classroom practices. The gains are consistent with a PD model that emphasized the iterative nature of scientific investigations. The following excerpt from an interview captures a common theme expressed by the teachers, “the iterative process of the workshop contributed directly to the improvement in the quality of scientific communication, captured by their posters”. The study contributes to a deeper understanding of ways to support teachers in promoting inquiry in their classrooms, especially in the context of scientific communication and claims based reasoning. This quote is important in that the difficulty addressed by Bartos et. al. (Bartos & Lederman, 2014; DiBiase & McDonald, 2015) scientific inquiry (Capps & Crawford, 2013) may not translate successfully in their classroom practices is addressed. The assertions presented below are supported by the data and rationale described in the analysis section.

1. Workshop participants increased their scientific communication and gained practical skills in scientific communication
2. Teachers’ understandings of using evidence and reasoning to support claims improved during iterative inquiry chemistry workshop
3. The iterative nature of the iterative inquiry chemistry workshop facilitates an increase
in teacher’s inquiry understanding

Research projects all have limitations based on various criteria, for example sample size or bias. Our research sample size is seventeen participants divided into 4 groups in a single setting. One of the limitations of this study is lack of a control group to measure more accurately the professional development’s impact on the classroom. Additionally, more quantitative data describing inquiry instruction before and after the workshop could have been captured by video recording lessons prior and after the professional development experience. The increase in data could more illuminate the PD’s impact.

**Future Work**

Capp’s (2012) review revealed inclusion of curriculum development in professional development experiences is important. During the subsequent design of the next PD, one recommendation for change to improve our PD model would be to provide an opportunity to integrate an inquiry-based lab within each teacher’s current curriculum. This would be a natural transition for participants to envelop inquiry instruction into their current curriculum. Capp’s (2012) research also reveals the importance of a continued collaborative environment following the workshop. An additional recommendation for our study includes supportive collaborative discussion after the workshop. The inquiry-based laboratories alignment in curriculum creates a natural opportunity for continued supported collaborative discussions revolving around the impact of the inquiry-integrated curriculum. A third modification to our PD model would be to incorporate previous workshop participants in facilitating subsequent workshops. The facilitator role strengthens understanding of the iterative process and solidifies nuances for individuals conducting the workshop. Another modification to our PD model would be to provide opportunities for integrated based lab work.
One of the limitations in our study, lack of a control group, could be addressed by including a control group that receives a typical PD (no iterative inquiry-based laboratories). This additional element would provide the study a more accurate measure of the professional development’s impact on the classroom. An additional limitation of our study, the lack of measurement of participant’s inquiry instruction before and after the workshop could be addressed. Quantitative data describing inquiry instruction before and after the workshop could have been captured by video recording lessons prior to and after the professional development experience to assess the impact of the workshop on participant’s inquiry instruction.

In eradicating some of our study’s limitations with the mentioned modifications, our PD model could enhance the experience of subsequent participants. Additional questions could be posed with the next version of the PD workshop such as: Are certain types of inquiry (guided vs. open ended) are more effective on teacher growth than others? During the iterative community discussion would a literature discussion or poster construction be more effective on teacher growth? Does a specific chemistry inquiry activity lend itself more to a literature discussion than a poster construction (i.e. Johnstone’s Triangle). Someone could study also design PD around loosely related activities (all involving some kind of inquiry) vs. a more closely, well-focused set of sequential problems.
REFERENCES


APPENDIX 1 POSTER RUBRIC FOR ITERATIVE INQUIRY

CHEMISTRY WORKSHOP

<table>
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<th>Components of Informational Elements</th>
<th>Not Present (Absent) 1</th>
<th>Emerging (Basic Understanding) 2</th>
<th>Developing (Tentative Skills) 3</th>
<th>Proficient 4</th>
<th>Skilled 5</th>
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**INFORMATIONAL ELEMENTS**

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<th>Author</th>
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<th>Authors listed with credentials and serially according to their contribution in the project</th>
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<td>Excessive use of text with no illustrations</td>
<td>Minimal use of illustrations</td>
<td>Appealing combination of illustrations and text, no color, detail not visible from 3 feet away</td>
<td>Reasonable balance of illustrations and text, some color, visible from 3 feet away</td>
<td>Appealing combination of illustrations and text, appropriate font, and color is used appropriately, visible from 3 feet away</td>
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<td>Provides adequate background and justification using range of resources</td>
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<td>States why this particular method was selected and gives an example of another plausible method and reason it was not selected</td>
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**Research Question** (Russell & Good, 2011) (MacIntosh-Murray, 2007)

| Activity | carried out but fails to provide the overall picture | carried out and provides an overall picture but not clear and succinct (may be unnecessarily wordy) | picture, and what they expect to accomplish by carrying out this activity |

**Abstract**

| Abstract is not provided | Abstract is not clear or easily understood and grammatical errors | Abstract is clear, grammatically correct, and understandable but incomplete | Abstract is clear, grammatically correct, understandable but not succinct |

| Question is testable but broad and unclear | Research Question is testable, narrow, and understandable but do not include all of the following: At least two variables (independent and dependent); the variable can be tested; a cause and effect relationship; and specific parameters stated | Research question is narrow, testable and includes: at least two variables (independent and dependent); the variable can be tested; a cause and effect relationship; and specific parameters stated |

| Researchable within given time frame | |

**DATA DERIVED ELEMENTS**

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**DATA DERIVED ELEMENTS**

| Unique application of research method, builds on primary interest |
| States why this particular method was selected and gives an example of another plausible method and reason it was not selected |
| Explains succinctly yet |
| Method was selected and gives an example of another plausible method and reason it was not selected plausible method and reason it was not selected Either of the following elements were present but not all: Explains succinctly and clear: identifying dependent and independent variables, why particular variables were chosen to be dependent or independent, how data were collected, how variables were controlled, data analysis techniques. |
|---|---|---|---|
| **Materials/Apparatus used during scientific investigation** | Does not identify the materials/apparatus used Identify only one material/apparatus used Identify some of the needed and appropriate apparatus/materials used during the investigation Identify most of the needed and appropriate apparatus/materials used during the investigation Identify all needed and appropriate apparatus/materials used during the investigation Safety measures identified |
| **Observation** (Halonen et al. 2003) | Observes behavior superficially Observes general pattern, confuse observation and conclusion Observes holistically and distinguish between observation and conclusion Observes small subtle observations distinct from conclusions Sophisticated or detailed observational techniques applied |
| **Evidence/Claim Reasoning** (Halonen et al. 2003) | Lacks evidence, claims and or reasoning In coherent and does not connect evidence, claim and reasoning Weak/insufficient connection between evidence, claim and reasoning Coherent and integrated claim based on evidence and reasoning Compelling claim based on evidence and reasoning; Mentions and explains limitations; |
| **Visual Representation** Table, Image, Figure Not Provided Minimal representations and connection between figures and evidence Sufficient representation that support evidence and are referenced in claim  In case of graphical representation, only one of the Sufficient representation that support evidence and are referenced in claim; include macro/micro world representation In case of graphical representation, either of the Complex representations that support evidence and are referenced in claim; include macro/micro world representation In case of graphical representation: each axis is labeled correctly and measurement units are identified for quantitative |
Components of Conclusive Elements | Before Training (Baseline) | Emerging (Basic Understanding) | Developing (Tentative Skills) | Proficient | Skilled
--- | --- | --- | --- | --- | ---
Components of Conclusive Elements | Overall Argumentation Skill (Halonen et al. 2003) | Argues based on common sense, accepts personal experience as conclusive | Uses basic concepts to develop simple argument, limited audience awareness, argue from personal experience | Develops plausible argument, aware of audience through engaging language, assumes consistent audience knowledge | Articulate argument using examples and supports | Complete argument with attention to subtle meaning of content, defends against critics
Conclusion/Results (Russell & Good, 2011) (MacIntosh-Murray, 2007) (Matthews, 1990) | Missing conclusion | Conclusions inconsistent and remotely related to data analysis | Conclusion is partially valid based on the data presented and analysis | Conclusion is valid and loosely based on interpreted data and shows connection between relevant data analysis and conclusion Conclusion is based on the data and analysis, but demonstrates only partial understanding. | Conclusion is valid and appropriately based on interpreted data and shows connection between relevant data analysis and conclusion; Conclusion demonstrates synthesis of understanding results and implications going forward
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APPENDIX 2 POSTER RUBRIC SCORES FOR JUDGES 1 AND 2

Poster Rubric scores for Judge 1

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| Observation   | 2        | 2        | 3        | 5        | 3        | 1      | 1      | 1      | 5      |
| Evidence,     | 2        | 4        | 4        | 4        | 4        | 2      | 2      | 4      | 4      |
| Claims,       |          |          |          |          |          |        |        |        |        |
| Reasoning     |          |          |          |          |          |        |        |        |        |
| Visual        | 1        | 2        | 3        | 3        | 4        | 1      | 2      | 4      | 4      |

## Conclusive

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| Conclusion    | 1        | 1        | 1        | 1        | 1        | 1      | 1      | 1      | 1      |
| Future        | 1        | 1        | 1        | 1        | 1        | 1      | 1      | 1      | 1      |
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APPENDIX 3 PRE-PROFESSIONAL DEVELOPMENT SURVEY

INSTRUMENT

Name: ___________________

Before we begin, we’d like to find out your thoughts on a few topics that deal with thinking about chemistry and communicating chemistry, especially as it pertains to what goes on in our classrooms. Some of these topics may be asked about again near the end of or after Summer Academy. The answers will help us as a community to understand the importance of using models, thinking about chemistry, communicating science, and developing effective classroom strategies.

1. How would you describe what a scientific model is to someone who is not familiar with models?

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
3. What aspects of scientific modeling are important for your students to learn in your classroom?

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?
5. Sometimes we want to facilitate inquiry-based activities with our students with the goal of thinking deeply about the chemistry we can observe and to connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?

6. Sometimes we want to facilitate inquiry-based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?
7. Please provide some information about your science, math, and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.

Chemistry:

Math:

Science:

Teaching Experience:

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.
APPENDIX 4 POST- PROFESSIONAL DEVELOPMENT SURVEY

INSTRUMENT

Name: ___________________

Now that we are near the end of Summer Academy, we’d like to get your feedback. Some of the questions are the same as you did at the beginning. However, there are some additional questions at the end to get your feedback on what we did.

We encourage you to describe your thinking in words and other modes of communications.

1. How would you describe what a scientific model is to someone who is not familiar with models?

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
3. What aspects of scientific modeling are important for your students to learn in your classroom?

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?
5. Sometimes we want to facilitate inquiry-based activities with our students with the goal of thinking deeply about the chemistry we can observe and to connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?

6. Sometimes we want to facilitate inquiry-based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?
7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experienced added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking.

8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.
APPENDIX 5 TEACHER INTERVIEW - 1 MONTH AFTER ITERATIVE INQUIRY CHEMISTRY WORKSHOP

- **Show teacher 1st poster on paper**

1. How did you communicate your findings from your first poster?

   Why did you choose these strategies?

- **Show teacher set of posters on paper**

2. What changes occurred from the first to the last poster? If so, why is there a change?

   - What is the importance of this change?

   - When the posters were presented, you had a chance to discuss your poster and be asked questions, How did that influence your subsequent poster?

3. Was the process of making the posters a model? If so, how did your methods of creating your model change?

   - Why did you change your method?

- **Show teacher micro-macro poster**

4. Focusing on this poster, what strikes you as important in this poster?

   - What are you attempting to convey with this poster?

5. How was your role at Summer Academy different than your role as a classroom teacher?

   - Was it beneficial to have a different role? How?
Mitchell and I hope that you are doing well. We would like to incorporate your expertise as we discussed during Summer Academy (2014). We envision you having an important role in this paper and we have a few questions to help us further develop a draft. We are hoping that we can meet in order to discuss the questions below at a convenient location and time.

1. What aspects of the Summer Academy might benefit other teachers? (Below are a few questions that could get you thinking)

   - Did the Summer Academy impact you as an instructor?
   - Did the experience modify your instruction?
   - Did the poster presentations impact your curriculum?
   - Has Johnstone’s triangle affected your thinking about chemistry and your instruction?
APPENDIX 7 DENSITY INQUIRY BASED LAB

You are given a block of clay and you cut it in half; predict whether the density of the ½ piece of clay block will be relative to the whole block?

What is density?

Can you measure density?

Materials:
- Scale
- Knife
- Calculator
- Water
- Graduated Cylinder
- Clay (multiple shapes)
- String
- Ruler

Choose one of the clay objects, imagine how you would measure density of clay using the materials listed above; in the lines below explain your thought process.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

In your group, take a few minutes to discuss your thought process and make any necessary changes to your answer above.

Using the materials presented above, identify steps to calculate the density of the clay.

1.

2.

3.

4.

5.

Use the steps above to calculate the density of clay. Fix any steps listed above that require change.
Density of clay: ________________ Units of Density: ________________

Remove a portion of clay with the knife. Predict the density of the piece of clay and draw a picture to explain your answer below.

The density of the clay piece will be (less than / equal to / greater than) relative to the clay block. (circle your choice)

Picture to explain you density prediction.

Calculate the density of the clay piece using the same procedure as you used for the clay block.

Clay piece Density = ____________

Were your predictions accurate: Yes/ No

Why/why not were your predictions accurate?

Two blocks of equal volume are place in a bowl of water, one floats and the other sinks. Draw a molecular representation that shows the different densities of the two blocks

Was your initial prediction correct or incorrect, why?
"Shaggy" poster rubric scores by element, poster 1 (red, Soda Challenge), poster 2 (green, Density), poster 3 (blue, Slime)
"Bluebird" poster rubric scores by element, poster 1 (red, Soda Challenge), poster 2 (green, Density), poster 3 (blue, Slime)

"Uno" poster rubric scores by element, poster 1 (red, Soda Challenge), poster 2 (green, Density), poster 3 (blue, Slime)
### APPENDIX 9 PRE AND POST SURVEYS

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<tr>
<th>Teacher</th>
<th>Representation modeling</th>
<th>Submicro level understanding</th>
<th>Limitation of Models</th>
<th>Model Revising</th>
<th>Hands on Engagement</th>
<th>Deeper Student Thinking</th>
<th>Communicate Science</th>
<th>Misconceptions</th>
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1. How would you describe what a scientific model is to someone who is not familiar with models?
A scientific model would be a model of something we cannot see with our naked eye. A reference to something we think that it would look like at present time.

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2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit? It represents what we think certain atoms bond together with other atoms of the same kind.

3. What aspects of scientific modeling are important for your students to learn in your classroom? I think that it is important for students to cover as many aspects of scientific modeling as they can. They do not have Chemistry again until their sophomore or junior year in high school. They need to relate it to their everyday life to make it meaningful.

4. The Next Generations Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models? Some of the gifted students want to know what the correct answer or procedure is. They tend to want to get to the final correct way and sometimes have trouble with the inquiry base science. Its important for them to go through the process of learning and not always looking to the teacher to feed them the answer.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?
Again, to relate it to their everyday life. The hands on activities to discovery what models we go by now are essential to their understanding of aspects that they cannot see. Use of technology is very important so they can stay current with changes in science.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?

The groups work is very important, so students can listen and learn from each other. Research shows that students learn from each other and we need to provide them with this opportunity.

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.

Chemistry: embedded in the physical science
Math: 8th grade algebra, 7th grade math(pre-algebra) 6th grade math
Science: physical science
Teaching Experience: 25 years of teaching math science and social studies

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.

I just started the SEPUP chemistry and only got to the first section. My students really enjoyed it more than any other content that we covered. I would like to be able to go
Teacher 1

2 0 0 0 1 0 1 0 0 1

Teacher 2

1. How would you describe what a scientific model is to someone who is not familiar with models?
A model can be an illustration or device that is used to help someone understand an idea. For example, a model of an atom can be used to show locations of a proton, neutron, and electron.

2. In many chemistry curricula, students use representations of atoms, such as the atomic model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
The purpose of this kit is to show the different types of bonds. The advantages are colors and "limbs" connect the atoms of molecules - physically. The disadvantage is the color may be confusing when bonding atoms or molecules.

3. What aspects of scientific modeling are important for your students to learn in your classroom?
Construction, Hands on construction is important for tactile learners
Modeling helps students visualize abstract concepts
Modeling engages students in the learning process

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of
developing, using and revising models?
The advantages for developing, using and revising models are students become vested in their own leaning, students may extend their thinking (make a new idea), and help students analyze their thinking and looking for ways to improve. The disadvantages are this type of instruction takes time, Also, it may bests fit group instruction leaving the student who enjoys working independently.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? Principles that may be used all group activities, hands on manipulatives, and time to share ideas/thoughts

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? Intro and summary activities, model good questions

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.

Chemistry: high, college chem
Math: algebra 1, 2 trig, pre-calculus
Science: life, physical science
Teaching Experience: 6 years

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.

Teacher 2

Teacher 3

1. How would you describe what a scientific model is to someone who is not familiar with models?
I would explain to them that a scientific model is something that attempts to explain a scientific phenomenon. The model represents what we currently know/understand something in science.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
The purpose of a kit like this is to get kids to think about atoms their makeup and how they behave. Advantage - Helps kids with the vocabulary used in the study of chemistry. Disadvantage - Gives kids a false sense that they think they know everything about atoms.

3. What aspects of scientific modeling are important for your students to learn in your classroom?
My students need to understand that modeling in science can help them understand concepts and
that models can change as new knowledge is gained.

4. The Next Generations Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?

Advantage - Using models in chemistry helps students think about the model and decide how the model represents a concept

Disadvantage - Students sometimes use a model as a crutch and limit their thinking

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?

Use of several modes of learning - visual, hands on, interactive

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?

Communicating to others involves skills

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.

Chemistry: Traditional college chem background - chem 1/2/organic chem
Math: Math concentration but not a major in college
Science: Biology/environmental background
Teaching Experience: 40 years teaching primarily science/biology and life science/Earth/Space Taught math to pre-algebra approx 10 years
8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.
Best practices of teaching chemistry

Teacher 3

Teacher 4

1. How would you describe what a scientific model is to someone who is not familiar with models?
A representation of a theory/idea supported by data that is easier to see than the idea/theory itself on the macroscopic level. It is usually not a perfect representation, but rather illustrates the finer parts.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
Purpose: Roughly illustrate connectivity at atoms and compounds Advantages: Bond connections, rotational ability, rough bond length, geometry Disadvantages: Pi vs sigma bond, scale/size, electron representation

3. What aspects of scientific modeling are important for
your students to learn in your classroom? To understand both the purpose of the model to aid in learning and the limitations of each model to avoid formation of misconceptions.

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models? For the most part, the NGSS ideals about using models should be purely beneficial with respect to chemistry. One major drawback that I could see is students construct knowledge being insufficient to formation of complex models to the macroscopic level with respect to the middle school age group.

5. Sometimes we want to facilitate inquiry-based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? The biggest thing is to plan inquiry-based activities around content that can be explained with models on the macroscopic level and then tested in labs. Using peer discussion in some prelab modeling time will allow for a deeper understanding of the content. Careful lesson planning and proper group structure will be essential to the success of any inquiry-based activities. 

6. Sometimes we want to facilitate inquiry-based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the
classroom to help students be successful at these activities? This again ties back to group structure, but also is heavily dependent upon available materials. Communication associated with an inquiry-level activity will only be as strong as the model students are exploring and forming. Activities that are poorly designed will lead to students struggling to align their content knowledge with what the activity calls for. Properly designed activities will make at closer to the statements what needs to be discussed and leaves little room for deviation from the proper path.

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy. Chemistry: General and Organic chemistry with lab, advance structure and mechanisms, PLTL Lab ta for gen chem and o chem
Math: Up to Calc 2
Science: taken all physical/social science course for BS degree
Teaching Experience: Lab TA/Mert/PLTL/Tutor gen chem and o chem

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.

My intention was to help with discussion from my experience.

Teacher 4

2 0 4 0 0 0 2 1 0 2
1. How would you describe what a scientific model is to someone who is not familiar with models?
A scientific model is something we use to explain or examine something that would be difficult to view otherwise to see what is happening scientifically.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
Students can see how atoms join together to make molecules. The advantages are that they can see how many molecules form the disadvantage is that it isn’t really the way they join with little tubes.

3. What aspects of scientific modeling are important for your students to learn in your classroom?
I would like students to learn how to use a model to show and describe phenomenon. I would also like them to learn how to develop models and discuss their strengths and weaknesses.

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models? Because a lot of what happens in chemistry is difficult to see modeling can help explain a lot of
concepts. It’s really hard to make connections for middle schoolers.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? I’m thinking students can observe things like reactions they can model it.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? Sketching and modeling and experimenting to draw conclusions about what is happening.

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy. Chemistry: In high school but have taught middle school basics, none in college. Math: Calculus but an sure I forgot everything I may have learned but love math and have taught up to HS geometry. Science: Love science in my next life I will be a field scientist I took enough tried to stay away from Anything too analytical. Teaching Experience: Math-Alg/Geom/6-8 Math, Science Physical/Life/Earth

8. Finally, please describe some of your expectations for the chemistry portion of
the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.
I am hoping to learn more about chemistry without wanting to bang my head. Blowing things up would be fun. I do know the more I understand the better equipped I am to teach my students, I would also like ideas for researching or seeing chemistry in our world.

Teacher 5

Teacher 6

1. How would you describe what a scientific model is to someone who is not familiar with models?
A scientific model is a representation, usually visual, that can be used to explain, replicate, and/or investigate a phenomenon. X

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
These models provide a good 1:1 understanding for students that every ball represents an atom, and every stick represents a bond. It reinforces the idea of conservation of matter by showing students that all parts of the reactants end up in the products, and that they only ingredients in the products are those that were already present in the reactants. Some disadvantages are that it doesn't show what kind of bond, or number of electrons, or usually relative sizes of atoms. X X X
3. What aspects of scientific modeling are important for your students to learn in your classroom? All... Creating their own models. Testing models. Using them to explain a phenomenon rather than to show what something looks like. Collecting data from model (when appropriate). Sharing the model with others and getting feedback on it. Then revisiting it - iterating on it to refine their understanding.

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models? I don't see any disadvantages. I do think that it's often impossible for students to create/develop their own models as most students have already been exposed to multiple models by the time they take chemistry. Further, good teaching dictates that we expose students to multiple representations of ideas, and that we provide models of intended outcomes. All of this impacts model development significantly, but not necessarily using and revising. Creating models of invisible things is also a real difficulty for many students.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? Models,... Discussion. Collecting and analyzing data (things like massing...
materials before and after reactions).

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?


X X X

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.

Chemistry: Only taught it for 2 years. Haven't taken a chemistry course since 1992
Science: Teaching it for 10 years now. Science major in high school. Many bio. College courses.

Teaching Experience: 13 years total: 10 Science, 4 ELA, 8 Geography/S.S; 9 Health, 4 Technology

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.

I just want to learn more chemistry, and ways to teach it, so that I'm better at it.

Teacher 6 5 0 1 2 1 1 2 0 1 0
1. How would you describe what a scientific model is to someone who is not familiar with models? Any means of representing a phenomenon or process, useful to convey ideas or info.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
The purpose is to make visible and tangible the structure of matter at a sub-microscopic level so learners can better appreciate the concepts involved, e.g., bonding and structure, reaction mechanisms, conservation of matter. One disadvantage is the need for objects to represent forces/bonds, and these are also problems with scale and relationships, etc.

3. What aspects of scientific modeling are important for your students to learn in your classroom? They need to learn to make use of models and become familiar with manipulating things to learn about the matter and energy the models represent. They should have some opportunity to change models, invent their own ways of modeling knowledge, and note the benefits and limitations of various types of models.

4. The Next Generations Science Standards recommends that students should be engaged in
developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?

I don't think my 8th graders have sufficient background knowledge to develop their own models at the outset unless they have extensive guidance and/or direction. On the other hand, manipulatives and activity based lessons are particularly effective for engaging young learners and maintaining their level of interest and involvement.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?

I think the 3-D representations are great for starting the discussions and questions that are likely to lead to deeper thinking, and actively involving students in demos of ideas, even to the point of “student as particles” their motivation to learn is an important factor.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?

Working with vocabulary and pictures/video/manipulative s seems to be especially helpful. They need words to start the discussion and to label the new concepts.

7. Please provide some information about your
science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.

Chemistry: As a zoology major (30 yrs ago!) I took a full year of general chemistry and a full year of organic chemistry. I also worked for Dr. H. Patterson as an undergrad for a year, in his lab in Aubert Hall.

Math: Calc 1 and statistics
Science: mostly Zoology, one physics full year.

Teaching Experience: 27 yrs at middle level, 1 year high school chemistry

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.

Like the idea of "refreshing" what I know and considering ways to better communicate the pertinent info to my students.

Teacher 7

Teacher 8

1. How would you describe what a scientific model is to someone who is not familiar with models?
A model is a way of representing an object, process, system in a more concrete and simple way without a sacrifice of accuracy.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model
kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?

Purpose: to help student visualize the abstract process of bonding

Advantage: makes an abstract idea more concrete and simple way without a sacrifice of accuracy

Disadvantage: this model does not fit all situations

3. What aspects of scientific modeling are important for your students to learn in your classroom?

Using models to create a mental representation of an abstract concept, using models to gain a deeper understanding of chemical processes, using models to recognize the relationships and interactions of atoms, molecules, using models to show complexity

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?

Advantages: deeper understanding of abstract ideas, promotes a more "scientist-like" approach, (inquiry) more engaging for students

Disadvantages: time, materials, cost

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?

Models, modes of representation, thinking about bigger picture, real life applications
important to link the macroscopic result with the chemistry on molecular level and the representation of this using formula.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?

It would be important to facilitate students moving from "chemistry" language to atomic scale interactions it is very difficult for students to move from a chemical equation from letters and numbers to a visualization of the molecular process taking place.

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.

Chemistry: Gen chem 1&2, Organic chem
Math: algebra (Mat111), calc 1 (Mat126), precalc (Mat122), business (Mat 115), statistic (Mat 232)
Science: Genetics (Bio465), Biochem (BMB320), Biology of plants, microbiology (BMB300/BMB305)
Field Natural History (Bio205), Cell Bio
Teaching Experience: Only observations, various middle school and early high school bio/life science

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.

ideas for promoting deep understanding, collaboration with experienced teachers, use
1. How would you describe what a scientific model is to someone who is not familiar with models?
A visual representation of a scientific figure or concept

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
It allows students to create visual representations.
These kits can be very helpful for visual and kinescetic learners.

3. What aspects of scientific modeling are important for your students to learn in your classroom?
creates visual representations, hands-on learning experience, inquiry and collaborations among peers, increases student engagement

4. The Next Generations Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?
disadvantages: models can be a great representation however they are not always completely accurate (size)
advantage: visual model for students, collaboration and discover of concepts, inquiry based learning
5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? group work, hands-on learning experiences, technology that creates/shows interactive models modeling X X

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? different questioning techniques, teaching student how to be/think like scientists X

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy. Chemistry: completed chemistry classes in high school and during my undergrad at Umaine Math: graduated from Umaine with a major in mathematics, student taught at middle school and high school level Science: worked with SEPUP curriculum for 2 years, teaching partner for 1 year Teaching Experience: student taught for 0.5 year, teaching partner for 1 year

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell
Teacher 9

To learn strategies to help me become a more effective chemistry teacher.

Teacher 10

1. How would you describe what a scientific model is to someone who is not familiar with models?
   A way to describe or demonstrate a phenomena. It can be a picture, sentence, 3d model, or other representation that shows or explains how something is, works or will do.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
   Showing the basic representation of connections of atomic structure. Advantages include a visual understanding of how the structure “is” or connects with another atomic structure. Disadvantages include a lack of full understanding how the connections are made, energy transfer and movement.

3. What aspects of scientific modeling are important for your students to learn in your classroom?
   All revolves around energy

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and
disadvantages for instruction in chemistry of developing, using and revising models? Kids are all at different levels of understanding. Often they view themselves as wrong if their models are not like anothers. Developing models takes time...not a lot to work with in a classroom school year. Attitudes surrounding sci/chem have been traditionally tell me and I'll know, rather than lead me and I'll understand better.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?

Multiple opportunities to connect and discussions to help make connections X

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?

Same as above X

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.

Chemistry: Small unit on periodic table to 6th grade
Math: 6th grade year content for 16 years
Science: general science taught for 14 years using multiple texts 2 years earth
Teaching Experience: 17 years

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.

I’d just like a better foundation for my science background.

Teacher 10

2 0 1 1 0 0 2 0 0 0

Teacher 11

1. How would you describe what a scientific model is to someone who is not familiar with models?

A scientific model is a visual representation of an object or a process/concept.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?

The purpose is to give a visual aid to a concept or idea that may be held to explain verbally. Advantage: visual aid and viewable object. Disadvantage: kits cost money and need to be manufactured.

3. What aspects of scientific modeling are important for your students to learn in your classroom?

It is important to realize that the model is merely a visual representation that may closely represent the actual object/substance/process/idea. It is also important to realize the comparison with the
actual object/process to transfer the information from the model to the cognitive thinking of that process/object. It is also important to play and have fun to learn more effectively (hands on).

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?

Advantages: visual representation help with cognition, hands on experience, critical thinking to relay info from model to memory, its FUN

Disadvantage: some students only play with models and don’t transfer the knowledge to the brain

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?

Students should realize that his model represents a concept that may be to small or deep to comprehend.

Test/observe/understand the proficiency of the students to relate the model to the concept/object. Ability to explain the concept... with and without the model. Check for understanding between the model and reality

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students
be successful at these activities?
Ability to explain an unfamiliar concept/object with an explainable visual aid. The more senses a student uses to learn a subject/concept/idea...the better they will remember it. They then have multiple avenues to take to review that knowledge.

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.
Chemistry: 2 years high school, 2 years undergrad in college
Math: 3 years high school, 2 years college
Science: 4 years high school, 4 years (+) college
Teaching Experience: 2 years high school, 1 year middle school

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.
I would like to have hands on experience with models/experiments/concepts. I also would like to troubleshoot some lessons/activities that we are utilizing in our school.

Teacher 11

Teacher 12

1. How would you describe what a scientific model is to someone who is not familiar with models?
A scientific model is away to communicate your knowledge/understanding of a concept so that someone else can learn or understand more about a concept.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
   Using these kits helps students create a mental image/visualize something concrete when learning. Atomic structures of molecules. Helps to explain the bonds these molecules have and develop a better conceptual understanding of the material.
   Disadvantages might be constructing the models and not being able to draw structures (for exams and such) but the material should go hand in hand with the model-kit.

3. What aspects of scientific modeling are important for your students to learn in your classroom? Drawing (atomic structure, molecules..etc), written responses, experiment/activities/equations?

4. The Next Generations Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?
   Advantages: promotes conceptual understanding more way of communicating their knowledge/understanding, developing a scientific way of communication (how scientists actually do science.)
   Disadvantages: most classes are instruction based, how
do we incorporate these ideas into the classroom, inquiry learning/teaching is hard
5. Sometimes we want to facilitate inquiry-based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?
Their needs to be open discussion between students and educators so they can express their thoughts and develop a deeper level of understanding create an environment where students can share ideas, provide activities/labs that require the student to make hypothesis and predictions on their own
6. Sometimes we want to facilitate inquiry-based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?
Having open discussions within the classroom especially group discussions about common misconceptions, giving the students multiple methods for communication chemistry (text/draw/mm representation), lab groups presenting their findings in front of classroom
7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.
Chemistry: Chy 121/122, organic chemistry 1 and 2, chemical engineering courses
Math: calc1,2,3, diff eq with linear alg
Science: Phy 121/122 and other chem e courses
Teaching Experience: Spring 2014 Mat 103 Umaine

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.

to learn more about chemistry, learn what teachers want to improve in their classrooms and discover ways to help, to discover where the students understanding of material and how much they learn about chemistry.

Teacher 12

Teacher 13

1. How would you describe what a scientific model is to someone who is not familiar with models?
A model is something visualized in our tangible world that represents something that can't be seen or understood.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
The kit's purpose is to make tangible the bonds or interactions between atoms that would otherwise be impossible to visualize.

Teacher 12

Teacher 13

1 2 0 1 0 0 2 5 1 1 1 1

1. How would you describe what a scientific model is to someone who is not familiar with models?

A model is something visualized in our tangible world that represents something that can't be seen or understood.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
The kit's purpose is to make tangible the bonds or interactions between atoms that would otherwise be impossible to visualize.

Advantage- visualization, manipulation, tangible
3. What aspects of scientific modeling are important for your students to learn in your classroom?
- limitations of the model,
- the ability to develop a model
- models purpose, modelling link to thing that are impossible to visualize

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?
- Advantage: refining models allows for higher level thinking, using models makes one more familiar with limitations and purpose, in depth conversations focused on modeling subject
- Disadvantage: time consuming to teach skills, not part of standardized curriculum - what teachers are asked to do

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?
- articulate to each other what is happening, drawing, picture, diagrams less scaffolding over time to facilitate true inquiry based activity, teach about inquiry itself self reflective practice to see individual gains

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students
be successful at these activities? drawing, diagram, picture activities to aid in student’s ability to communicate, explain verbally to group members of other students, show good examples in order for students to mimic good communication, practice communication skills.

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.

Chemistry: Bs in chemistry, teach college chem at UMD, Husson, EMCC, Hermon
Math: love algebra, okay at calculus
Science: I love it, always learning it
Teaching Experience: 4 years k-12, 2 years at college

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.

learn more about the way student’s learn, communicate findings from 1st year of setup curriculum maybe inquiry based discussion, to implement more in classroom

Teacher 13

1 3 3 1 3 1 1 3 0 0 1

Teacher 14

1. How would you describe what a scientific model is to someone who is not familiar with models?
A model is a representation of a phenomena or relationship which can be used to communicate thinking, clarify ideas, and make predictions.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?

The kit helps students to model molecular structure with bonding. Students can represent something they can’t see (because of size) to explain the relationships they can also use this understanding to learn how other molecules bond together. The disadvantages are that they don’t perfectly represent the real thing.

3. What aspects of scientific modeling are important for your students to learn in your classroom?

It is important that students can explain how a model represents something well (advantages) and its limitations. It’s also important that they make predictions, collect data when possible, change their model as needed, clarify their ideas, develop questions based on the model, and be able to create their own models to explain their thinking.

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?

I find that assessing students; abilities in developing and revising models is difficult. It doesn’t fit well with our grading systems. Using models is more complimentary to assessment. Maybe
assessment
of developing/revising isn’t
necessary? These are big
questions I need help
answering for my classroom.
Modeling for instructional
purposes (and not
assessment) has many
advantages, such as
accessing kinetic learners
and requiring students to do
more than memorize
information. It usually
requires talking as well
which is needed to clarify
ideas. Disadvantage enough
materials, helping to revise
models transfer knowledge
to new model (like physical
to drawing)
5. Sometimes we want to
facilitate inquiry based
activities with our students
with the goal of thinking
deeply about chemistry we
can observe and connect it
to what might be happening
on the atomic scale that we
cannot see. What are some
of the principles we might
employ in our classroom to
help students be successful
at these activities?
Ensure that all students can
feel successful with some
part of the inquiring
process. Not all
students will reach the
higher level, deeper
thinking in the time that is
given. Students will need
several opportunities to
explore. Differentiation is
important to challenge all
students. Lots of
opportunities to speak to
one another, draw their
ideas, plan responses, revise
ideas, and make
their thinking public. This
process cannot be rushed.
6. Sometimes we want to
facilitate inquiry based
activities with our students
with the goal of helping
them communicate
chemistry. What are some
principles we can use in the
classroom to help students
be successful at these
activities?
Communicating ideas often
takes deeper thinking so
these strategies are not so
different. Opportunities for
different kinds of models is

X  X  X  X

X  X
important.

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.

Chemistry: Last course was environmental chemistry about 9 years ago.
Math: Many courses in math in undergrad school (about 9-13 years ago), some courses since for certification, classes through Calculus 2
Science: undergrad. Degree in environmental science concentration in Earth Sciences, MAT Physical sec. Ed.
Teaching Experience: Just finished 3rd year math science 7th grade

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.
Chemistry is not my strength, so hoping to deepen my content knowledge and feel more comfortable bringing introductory ideas of chemistry more into the 7th grade earth science curriculum.

Teacher 14

Teacher 15

1. How would you describe what a scientific model is to someone who is not familiar with models?
A tool that shows or demonstrates a key concept
in science (or other content areas).

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
To make the abstract more concrete for kids
To help kids more or rearrange materials making the molecule seem or appear more "real"
weakness - could (and probably does) create false ideas or mistakes in thinking by kids
can't go far enough in the process of molecular structure: limited used - models: sometime to kids they do not show the "what if's" to a concept

3. What aspects of scientific modeling are important for your students to learn in your classroom?
Modeling- a way to communicate ideas to others
a method of demonstrating potential weaknesses in a model when something does go as plan

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?
It is hard for 6th grade students to see beyond the model to take the model back from the concrete to the abstract level
Revising a model takes time and time is a finite quantity in a class that's 40 minutes long, so that's a potential problem. Kids might lose a sense of how the model worked from day to day
Advantage - model is more organic, as it is forever changing
5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? Demonstrate/show concepts multiple ways - use kids sense of wonderment about science, esp. chemistry. Provide information through student interaction what are the pluses and minuses of models - Understand how for a model can or can't go in explaining the abstract What's the difference(s) on how the brain comprehends concrete and abstract concept

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? Role modeling various way to communicate - Kids need to have examples of how to communicate Provide graphic organizers to help kids layout their thoughts A lot of group interaction provides for a stronger sense of trust for sharing ideas and results of what occurred with their models.

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.

Chemistry: College level course, Basic information taught in 6th grade classroom setting
Math: College level, taught math in focus grade 5
Science: minor in science in college (undergrad)
Teaching Experience: 36 years

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.
Provide models to be used

| Teacher 15 | 3 | 1 | 3 | 2 | 0 | 0 | 5 | 1 | 0 | 0 |

Teacher 16

1. How would you describe what a scientific model is to someone who is not familiar with models?
   It is a way to demonstrate how something works or looks like that is either too small, too large, too complicated to actually watch happen. Often times it is a concrete way of demonstrating a very abstract idea.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
   It (the model) shows students that molecules actually are connected to each other in unique ways. What happens with my students is that they begin to think that the molecules come in these colors can bond if they can connect them no matter what their charge is, and you really don’t have any idea that these bonds are invisible.
3. What aspects of scientific modeling are important for your students to learn in your classroom?
Size is for convenience, so scale is very important but still is very difficult to group redrawing the model or looking at the concept with a variety of models.

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?
My students struggled because they have not had experience with models. To develop their own meant they had sufficient content knowledge to do this. Most of my students had had little chemistry. To revise a model asked that a student have multiple experiences with models. Not true of my students.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?
Maybe is students were asked to draw and reflect on a regular basis (almost daily) we would get more in-depth thinking. I am hoping using talk science where you expand on other’s ideas will help draw out more thought instead of rushing on to answer the lab questions.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these
activities?

I have used "Expo" writeups where students have to communicate what they have discovered in more depth on one topic. These worked somewhat but I need to have more oral discussions where we really consolidate ideas before I ask them to work on a particular question with their group. We also need to talk more about just questions they are "wondering" about.

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.

Chemistry: 0 Maine courses, General Chemistry, Organic chemistry, Biochemistry
Math: 3 semester of Calculus, 4 statistics classes, numerous PD workshops in middle and high school math, Pascal and Fortran programming
Science: My undergrad was Wildlife Management but science strand (do not have this any more) I took all the engineering and pre-med level classes. My masters is Microbiology.
Teaching Experience: 25+ teaching mathematics and sciences (K-college level)

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.

Just to discuss way of making something that is so abstract more understandable and exciting to my students. Chemistry rules their lives.
1. How would you describe what a scientific model is to someone who is not familiar with models?
A scientific model represents a concept in a way that makes it easier to grasp. Models can be illustrations, animations, graphs, physical manifestations, etc.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
The purpose of this kit is to help students understand how atoms bond with each other. The advantage here is that this particular model allows students to bond atoms with like and different atoms. A disadvantage here could be that creating more complete molecules may prove more difficult with such a simple kit.

3. What aspects of scientific modeling are important for your students to learn in your classroom?
Student should create models that effectively explain the concepts covered in the inquiry-based activity. These models should vary from their classmates.

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?
The advantage of having students develop their own models is that it forces them to explain the concept they've learned about and after feedback, they'll have to critique themselves as well before revising sound model. Disadvantages could be that all the students create the same model and therefore students would lose the opportunity for abstract thought.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?

NA

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?

Helping students to communicate the chemistry they've observed can be done by having them create models of their own. When a student completes an inquiry based activity and

7. Please provide some information about your science, math and chemistry background as well as your teaching experience. This could be specific courses or an assessment of your familiarity with these topics. This will be used to help us understand how to deliver professional development during and after the Summer Academy.

Chemistry:
Math: I worked as a long term sub in a 7th grade classroom for 4 months and taught math on my 7 week student teaching placement
Science: 14 weeks student teaching
Teaching Experience: 14 weeks student teaching math and science

8. Finally, please describe some of your expectations for the chemistry portion of the Summer Academy. This will help me (Mitchell Bruce) for this week. Thank you.

Just to discuss way of making something that is so abstract more understandable and exciting to my students. Chemistry rules their lives.

Teacher 17

POST

Teacher 1

1. How would you describe what a scientific model is to someone who is not familiar with models?
The scientific model has changed from the traditional model. Now we need to allow, to help our students learn more, a more inquiry based model. For example, communication among groups, and whole group questioning what they think they know and how, knowledge by revision

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
The atomic model kits give representation to the micro world. They need to visualize in order to understand the sub-atomic world. One disadvantage maybe their understanding of bonds, but that can be

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The atomic model kits give representation to the micro world. They need to visualize in order to understand the sub-atomic world. One disadvantage maybe their understanding of bonds, but that can be
cleared up with discussions.

3. What aspects of scientific modeling are important for your students to learn in your classroom? Students need to feel comfortable to take risks and understand that we learn from misconceptions. More learning will take place with the scientific modeling that we are using now.

4. The Next Generations Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?
   Advantages: students expressing what they know or think they know is very important to start with. by inquiry based curriculum they can then discuss and question to obtain further knowledge. Revisions are important so they can go from where they were with their understanding and progress along the way.
   Disadvantages: Time of class periods

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?
   The triangle connection that we used will be very helpful in facilitating their understanding of science. The communication amount student is essential for learning to take place. Equal participation by students will help all learning in the classroom. We also need to allow time for revisions so they can see their growth in the
learning process.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? This tie in with the previous question. Small group work with time for groups to share out with the entire classroom population is very important.

7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking? This week was very important in helping me understand many of the chemistry concepts that I can go back and share with my students. I think the sharing out with all the groups was very beneficial because we were learning from each other. I would like to find out how to get the clickers so I could use them in class.

8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking. The 2 hour break and coming back seemed to extend the day a bit long. I would prefer to have an one hour break and get out early.

Teacher 1  0  2  1  3  0  0  5  1  0  2
1. How would you describe what a scientific model is to someone who is not familiar with models?
A model helps someone understand an idea. For example macroscopic (slime) gives us a visual pictures of the attraction between molecules. These physical and chemical representations help someone vocalize their thinking, so other can add or agree upon the understanding (idea).

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
The purpose of this kit can be used to display the attraction between atoms and or molecules. The advantages are as follows: tactile, visual, and spacial. The disadvantage is students can believe the bonds between atoms/or molecules is structural, not as an attraction between two or more particles.

3. What aspects of scientific modeling are important for your students to learn in your classroom?
The aspects of scientific modeling are giving students the option to express themselves in multiple ways through graphs, table, or other manipulatives. Models can also be used by students to teach their classmates. Scientific modeling can be used to show growth overtime therefore increasing student confidence.
4. The Next Generations Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models? The advantages for developing, using, and revising models are allowing students to develop their thinking over time. This helps a student to analyze their thinking and develop new questions. A disadvantage is that students can develop misconceptions during this process. For example, bonds between atoms can be viewed as structural not as an attraction.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? Hands on investigations like the slime lab used the physical properties of moving PVA and sodium borate (slime). Next paperclips (connecting) were used to illustrate the connects between molecules. This activity took the seen and help explain the unseen.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? Models like poster show personal expression of knowledge discussions are used to explain thinking communication increases student’s understanding.
communication builds confidence and respect

7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking?

Density, slime lab, and submicro/macro representation were valuable. Teamwork developed partnership that helped understanding the PSP. Communicate, respect, and community will be taken home. Models show thinking - ideas of success and ones of improvement

8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.

NA

Teacher 2

Teacher 3

1. How would you describe what a scientific model is to someone who is not familiar with models?

A scientific model is a representation of some phenomenon. We can better understand the big picture (macro) if we understand the micro.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
The purpose of using the above representation of atomic models is to give kids a place to begin to think about atoms and molecules. Good - can bridge the gap to more complex or different ideas. Disadvantages - kids get stuck on a model and cannot expand their thinking.

3. What aspects of scientific modeling are important for your students to learn in your classroom?

NA

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?

Advantages of using, revising, developing models - expands thinking and understanding allows rethinking and revising promotes discussion and communication disadvantages takes time to work through models state does not assess science in this area

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?

Principles to help students communication skills collaboration willingness to be persistent

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students
be successful at these activities?
Inquiry based activities – communication develop activities that teach kids now to be a part of a team with kids disconnected physically (not electronically) They do not know how to interact with live people
7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking?
Activities I found valuable - Looking at micro macro parts of inquiry lab activities bring meaning to content poster making - helps with engagement even with less knowledgeable students Teamwork - group dynamics/ respect
8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.
Long lectures - would not have been very effective

Teacher 3

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Teacher 4

1. How would you describe what a scientific model is to someone who is not familiar with models?
A method for representation, and or microscopic phenomena in a visible manner.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do
you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?

Show the connectivity of atoms to each other and dedicate source facts as to the 3d bonding of the atoms to each other. Advantages: generate relation, connectivity, see differentiation, flexibility

Advantages:
- scale,
- misconceptions about bonds, misconceptions of atomic structure

3. What aspects of scientific modeling are important for your students to learn in your classroom?

Students mainly should focus on the primary content the model is conveying and its shortcomings. Discussion of said shortcomings are critical to avoid forming misconceptions of material that would otherwise be an excellent model.

4. The Next Generations Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?

To my mind, I only see advantages to the development, use and revision of models in density. Making macroscopic analogies to microscope phenomenon is one valuable method to learning chemistry. Revision of the models is the most important part for it allows for review of material and acknowledges that no model is ever perfect.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we

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cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? These all ties into the context theme of the weekly work, that being modeling. Open chemistry poster presentations, and synthesis of models/demos are excellent ways of encouraging students to think deeply about what can be observed and what is occurring on the atomic scale in chemistry.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? Limiting the instruction is key to an inquiry based activity in that students should not be given a goal to achieve. Provide and learning something new from the activity. Allowing them to explore a point of interest within an activity centered around exploration and discussion should be the ideal in promoting communication of chemistry.

7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking? Honestly, every activity completed in the set chemistry strand contributed positively to the experience of the week. The glue lab was probably the best as it provided inquiry within the groups, practiced the notion of peer-review, and exemplified the micro/macro/representation triangle at inquiry based science.
8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.

Parts of the presentation on Wednesday afternoon seemed to apply to only a few people and the room based on the limited participation on the lengthy discussion. The analogy of pre/post survey data is important but perhaps the presentation could have been done in such a way that it was more applicable to a larger segment of the strand.

Teacher 4

Teacher 5

1. How would you describe what a scientific model is to someone who is not familiar with models?
I would describe it as a representation of something or phenomenon that is hard to explain or see that helps us to explain or visualize it.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
The purpose of the models is to see how atoms combine to form molecules. The advantage is students can explore and experiment with it. The disadvantage is that student may think bonds are actual things or that everything is always a certain way.
3. What aspects of scientific modeling are important for your students to learn in your classroom?
   How to use a model, How to develop a model, how to revise a model. Are all important. Equally important is learning what is good about a model or realistic and what is not so good or limiting.

4. The Next Generations Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?
   It would be very difficult to teach chemistry without the use of models. Chemical equations atom and molecule representations properties of substances etc. all are better understood through models- Revising a model as we learn more can help students to understand phenomenon in a better way.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?
   Have them see certain phenomenon or experiment with an idea and see what questions might arise that students might want to investigate further as students develop procedures and observe results they will come to better understandings of these ideas.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some
principles we can use in the classroom to help students be successful at these activities?

The use of posters was instrumental in helping us to formulate our ideas and communicate those ideas to each other. Using words, tables, graphs, and diagrams allows students to think about what’s happening in a variety of ways. The act of presenting these posters helps students learn how to explain their reasoning to others.

7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking.

Several diagrams used - Posters, Graphs, Teamwork, Lab Work, Discussion, Tables, Modeling All of these things I can incorporate into my classroom. Some I already do, but some I could do more of.

8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.

I think the labs and group work were all valuable to me…. I can’t think of anything I would want to get rid of. I would only add blowing something up.

Teacher 5

Teacher 6

1. How would you describe what a scientific model is to someone who is not familiar with models?
A scientific model is a (usually visual) representation of a phenomenon intended to explain, clarify, question, predict, etc., something about that phenomenon. They all have limits.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?

These kits are "hands on", which is their biggest advantage. Allowing students to physically manipulate "atoms" and "bonds" helps concretize some basic, "invisible" (i.e. sub micro) concepts in a way that makes sense.

Some dangers are that students may believe things like, "bonds are physical structures," or "all atoms are solid spheres."

3. What aspects of scientific modeling are important for your students to learn in your classroom?

All... Trying to develop their own models. Trying to turn mental models into physical/visual representations. Testing models. Using them for applied purposes to actually try to explain phenomena. Sharing models. Eliciting and incorporating feedback about their models. And going back and revising their own models to include what new stuff they've learned. Also, recognizing the "good" and the "bad" in their own models and others.

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?
I don't see any way of all to understand chemistry without using models. The only potential disadvantage is that a model can reinforce or instill a misconception based on its particular limitations so the limitations of models needs to be included in instruction and discussion.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? Models! Multimodal representations. Inquiry! Discussions. Lots of exposure. Many hands-on experiences tied to the same concept to allow understanding to develop over time. Pretty much everything I wrote in response to question 3.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? Poster sessions. Clickers. Student rubrics where students evaluate other students. Modeling by instructor/peers. Exemplers. "Cheat sheets" of the principles of effective communication. Lots of practice. Small group discussion leading to whole class discussion.

7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking?
SA strand - All teamwork - Yes classroom - Yes
I loved Johnstone’s Triangle. I will definitely have it in mind during instruction; and not just in chemistry, but in all the science I teach. The known vs. unknown model of the scientific method. How Redox reactions work. Making sure that after labs/activities we take time to model/explore the submicro underpinnings of what we experienced!!

8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.

SA Strand – none I liked the demos. A few more would be good… and couple of explosions would have been appreciated. Everything else was great! I learned a lot! Thanks!

Teacher 6

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Teacher 7

1. How would you describe what a scientific model is to someone who is not familiar with models?
Any way of representing something else, especially something not visible.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
So students can visualize and "observe" bonding and stoichiometry first hand. an advantage is that the model demonstrate conservation of mass, but the need for solid objects to represent bonds/forces

X X
would be a limitation

3. What aspects of scientific modeling are important for your students to learn in your classroom? I'm not sure how to answer this - All aspects are useful in improving understanding. I felt that any successful experience they have with modeling in science is potentially beneficial.

4. The Next Generations Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models? Young learners are frustratingly concrete thinkers and many are unable to hold and manipulate abstract ideas about forces and sub-micro objects. Models are hands-on, minds on ways to engage them in this type of thinking. They also may be instructed on strongly-held misconceptions when they can "see what you're saying."

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? The mere act of involving and engaging students is likely to cause them to keep their attentions focused on the learning. Also, learning in a social activity particularly at their age - they need to talk to each other and are not good at sustained solo efforts like reading text or waiting.

6. Sometimes we want to facilitate inquiry based
activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? again, there is a need for vocabulary so that discussion can happen. They must be able to label objects and events in order to discuss them, and they need time to process and interact with them.

7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking? Yes, the teamwork is always a better way than any isolation could ever be. I already like lots of these ideas but I like the triangle for the visual reminder of the need for models and lab work in connection with the invisible phenomenon to make sense of it all.

8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking. I think I’d suggest using the grade-level standards and tailoring the activities to fit what our students need to know and be able to do. The e-configuration, for example, was a nice refresher for me but not useful for my students as it’s way beyond their level of understanding.

Teacher 7

Teacher 8

Teacher 7  2  2  1  0  2  0  2  1  0  0

Teacher 8
1. How would you describe what a scientific model is to someone who is not familiar with models?

A model is anything that represents a system or relationship—often that you cannot see. It can be a drawing, an analogy, or a physical structure that conveys the system or interactions.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?

This is an example of a model. These kits are very important—they help link the submicro level to the macro level. It can be difficult for students to develop understanding of submicro interactions because they cannot actually be observed. Advantages—Disadvantages—again money and funding limitations—the model can some time be misleading or not work well for all situations.

3. What aspects of scientific modeling are important for your students to learn in your classroom?

Modeling is important because it provides students with a physical representation of an abstract/submicro process. This helps create a mental representation of the topic, helps provoke deeper questioning and deeper understanding. They also require students to use a lot of complex thinking skills and develop their critical thinking and problem solving.

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for...
instruction in chemistry of developing, using and revising models?
Advantages - students learn chemistry at a much deeper level. Creating these models take much more higher order thinking skills. Students can also learn so much by receiving feedback and revising their Models disadvantages - although this produces much deeper understanding, it takes time and as a result, the class cannot cover as many topics compared to "lecture style" class

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?

Johnstone Triangle - The triangle helps us make sure that students have each of the 3 parts of the triangle. Having each of the three parts truly helps students understand a process. We normally only see macro scale changes, but thinking about how the macro scale is determined by what is going on at the submicro scale and how we choose to represent it is important to help students be successful and think deeply about chemistry

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? communication and being able to successfully share and represent your ideas is a vital part of doing science. You may have made an excellent discovery, but that
is only as strong as how well you are able to communicate your findings. I believe posters detailing, claim, evidence and reasoning and having students present their ideas is an excellent way to practice this skill.

7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking?

Teamwork added great value a real sense of community developed over a short period of time. Comparison of final products (the posters) showed us how much we had grown and developed our skills. When I become a teacher I will bring to my classroom the idea of creating a product with multiple modes that effectively communicate our understanding.

Also the comparison of the final products showed us how much we had grown and developed our skills. When I become a teacher I will bring to my classroom the idea of creating a product with multiple modes that effectively communicate our understanding.

8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.

All seemed to serve a purpose in either developing chemistry content knowledge, inquiry strategies, classroom curriculum etc. The only thing that I would suggest is to develop a stronger sense of security and community before asking the clicker questions. Many teachers were embarrassed by what they did not know.

Teacher 8
1. How would you describe what a scientific model is to someone who is not familiar with models?
A model is a representation of a phenomenon that we may or may not be able to see or understand. It could be a picture, a video, a sentence, a 3D model, or an acting/drama representation.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
It is used to put a face to a concept, a name or value to a phenomenon for us to understand. Advantage: the representations can be close to the actual. Disadvantage: the representations can be really different, but it is the connection we make to it.

3. What aspects of scientific modeling are important for your students to learn in your classroom?
Getting their hands "dirty" and showing their knowledge and how phenomena work, not just reciting the factual knowledge. It helps to "explain" or detail the why it is the way it is. It gives them a chance to "work it" and then ask "what if I" to change variables and see what happens. It gives them the opportunity to expand, question, and engage in the concepts being looked at.

4. The Next Generation Science Standards recommends that students should be engaged in developing, using, and revising models. What do...
you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?
We are getting better at developing models to understand our world, to represent it. What we need to do more is allow students to use it to explain further or associate it to another "issue" and by revising the model, we allow students to solidify the knowledge and add the new knowledge they learn while communicating their models to others- their "community" Disadvantage to that is it takes time to do it. But, the more we do it the less time it takes since we refine our methods of communication.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? Giving multiple way to represent findings and multiple opportunities to do so - allowing for an ability to gain strength and confidence. Reconnecting to previous activities to see or illuminate connections made. Reinforcing a community of thinkers to be able to promoting. Gain confidence to think further and want to think further.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?
Same as above- multiple ways and multiple opportunities - promoting community
7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking.

All activities were valuable to me to build on my knowledge base. The activities also were shown in a way to help progress thinking, building upon a concept and strengthening it. I will refine my use of Communicating activities to help students think more of refining editing and using them to deepen their understanding more. I feel I have short-changed them due to time constraints. Reporting out more and reflecting more are my goals for this coming year. I need to get them thinking more.

8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.

NA

Teacher 10

<table>
<thead>
<tr>
<th>Representation modeling</th>
<th>Submicro level understanding</th>
<th>Limitation of Models</th>
<th>Model Revising</th>
<th>Hands on Engagement</th>
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</tr>
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</tr>
</tbody>
</table>

Teacher 11

1. How would you describe what a scientific model is to someone who is not familiar with models?

Scientific method is the process by which questions get asked, tested and analyzed to produce an outcome or conclusion (claim). It has no set order, but it does have critical steps that must be included to be valid and complete.

2. In many chemistry curricula, students use
representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
The model is used to represent something that is difficult to explain or observe. It allows a visual representation of a concept. 

Advantage: visual representation, different way to learn, help conceptualize a concept that is unseen

Disadvantage: sometimes confusing if it represents something that is physically very different ie or tangible bonds representing invisible attraction, ie a solid represents a liquid

3. What aspects of scientific modeling are important for your students to learn in your classroom?

how to analyze the model and understand its analogy to the concept that it represents

why they are using a model what it represents it if is a proper representation that it is not the real thing...and how it is different

4. The Next Generations Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?

advantage: progresses science knowledge, inquiry and cognition in developing an accurate representation, different way to learn a concept, critical thinking and science knowledge, so they understand cognitive revisions are integral to science

disadvantages: not always a good representation of the concept, time consuming (but, so what), sometimes costly (in today budget cut
5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? Helps them understand that the model is just a model and that the actual concept is different helps them be successful through inquiry and revision helps think tangibly about something that isn't tangible demonstrate the process and modeling to the, but let them be creative and innovative in the process of creating their own model relate deep/unseen/minute/difficult concepts in a visual representation, discuss revise knowledge helps them understand that the model is just a model and that the actual concept is different helps them be successful through inquiry and revision helps think tangibly about something that isn't tangible demonstrate the process and modeling to the, but let them be creative and innovative in the process of creating their own model relate deep/unseen/minute/difficult concepts in a visual representation, discuss revise knowledge 6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? teach them how to use modeling to successfully understand or relax their knowledge demonstrate proper modeling, use models to discuss concepts demonstrate different modeling for the same concept X X XX X X 7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking? all the activities were valuable, the teamwork was enriching, enlightening and
successful
others collaborative ideas
were valuable and
enriching, many of the
concept/ideas/modeling
will transfer nicely into the
classroom slime is good,
models are excellent
I still hate posters...even
though they are successful
in illustrating collaborative
work and knowledge
8. What activities did you
find that were not very
valuable in the chemistry SA
strand? What
might you change or
eliminate? Please explain
using any modes that help
illustrate your thinking.

I liked the whole week, but I
would try get outdoor and
do science, more. Loved it.

Teacher 11

Teacher 12
1. How would you describe
what a scientific model is to
someone who is not familiar
with models?
A scientific model is a
tangible representation of
science concepts, a way to
express information
concepts and communicate
your understanding to a
community/audience.

2. In many chemistry
curricula, students use
representations of atoms,
such as the atomic-model
kit shown below. What do
you think is the purpose of
using a kit like this? What
are the advantages and
disadvantages of this type
of kit?
The purpose is to help
create analogues thinking, a
way to represent what
happening at the
microscopic level.
Advantages- help students
visualize compounds/
molecules bonding a way to
represent geometry of
molecules. Disadvantages -
physical bonds isn’t the best

X X X X
way to show bonds creates misconception that bonds are connecting rather than attracting.

3. What aspects of scientific modeling are important for your students to learn in your classroom? That there are multiple ways to represent or model the phenomena under discussion. Models can be revised it’s a way to represent your understanding and communicate it to others macro/micro representations

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?
   advantages: helps foster the idea that the students ideas are valid, allows them to think long about concepts, gives them the opportunity to communicate with peers (real world science) develop a deeper understanding of the material, doesn’t discourage students from sharing ideas, helps with misconceptions
   disadvantages: lengthy (time-restraints), hard to incorporate into a classroom.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? Again I think group discussions are key clicker questions or mini quizzes that you can discuss as a whole allow them to work independently, little direction
6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? Have classroom discussions about these activities, feedback from peers don’t give them the answer. Let the students arrive at an answer/decisions on their own posters or some way to communicate these ideas let them be wrong.

7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking? the experiments and posters were the most valuable and a great way to think about doing labs in a classroom. The teamwork was definitely an added value, allowed some great discussion and we to understand better how everyone was thinking about the same problem/concept. I also enjoyed the chemistry content strand, refreshed my mind on the concepts I had once learned (orbitals/balancing equations) clicker questions were great.

8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking. I enjoyed everything but the more activities/labs/demonstrations the better. I would have enjoyed a discussion about the curriculum (just because I’m not familiar with it) so I could have a better idea of what middle school students are learning.
the balloons could've been utilized better, I think, more instruction maybe (make the geometric shapes?) Balloons images of tetrahedral, tri planar, linear

Teacher 12

Teacher 13

1. How would you describe what a scientific model is to someone who is not familiar with models?
Model is something that can be be used to express micro (unseeable) and macro (seeable). These can be used to explain/challenge phenomenon in the real world

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
to visualize the micro world, make sense of reactivity, explain spatial relationships (bonding, hydrogen) advantage- visualize unseen phenomenon disadvantage- all models have weaknesses where they break down

3. What aspects of scientific modeling are important for your students to learn in your classroom?
revision of models, designing/building them, relating them to real life phenomenon discussing them, critically thinking about their strengths and weaknesses

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of
developing, using and revising models?
Advantage- develop-create a mental model to real life phenomenon, using -see where models break down, to explain anomalies, behavior that is unusual revise- continue to build new or refine inaccurate or incomplete models.
disadvantage- hard skills for students and teachers to understand, takes time in the classroom, necessary to teach limitations.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?
creating models, multimodal presentations, revising their model, more inquiry based labs, forum for model discussion, posters similar to the ones we made, individuals challenge their models, team work

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?
posters, discussion, community discussions of other posters, multimodal representations, team work talk about thinking, safer classroom environment

7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking? all of them- but for different reasons, I think teamwork
was the value— the most important aspect yes into physics classroom as well, poster community pic, inquiry based lab pic, teamwork pic, model revision pic

8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.

NA

Teacher 13

5 2 3 5 0 0 5 0 0 2

Teacher 14

1. How would you describe what a scientific model is to someone who is not familiar with models?
A model is a representation (for macro or micro phenomena or relationship) that helps you to create reasoning, communicate, clarify ideas, work out misconceptions, make predictions, ask questions, make claims, and create analogies.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
The kits allow students to use their understanding of electrons and bonding to make representations of molecules and reactions. Students can build understanding of what they see happening in the macro world to what is happening at a micro level. Students can then make connections to begin asking questions and leading their own inquiry. The advantage are
listed above, but the disadvantage may be in the misconceptions like that atoms are physically bonded, or that the model is always limited in its representation of the real thing.

3. What aspects of scientific modeling are important for your students to learn in your classroom?

It is important that students can use, develop, revise, and create models. Students should know why a model is used, which means understanding scale and representation. Students should also be able to evaluate a model for its limitations, misconceptions created, and how it represents the real "thing".

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?

Students in middle school have a difficult time with thinking at the micro level because atoms and molecules are so unlike anything they already know. They must also understand charges (+1, -1, 0). The rules in representation, such as with Lewis structure, is unique and takes practice to understand. All of these concepts can be complex, so students shouldn't be given a crash course in any of these concepts. They should be integrated into many of our discussions and activities to build knowledge. It also need to come from their thinking.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we
cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?
Ensuring that students are doing the work of creating explanations through claims, providing evidence, and reasoning. These concepts need to be discussed, ideas revised, and models developed to allow for deeper thinking.
6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?
Discussions are critical to developing ideas, revision, and gathering information from others. Making thinking public is important for empowerment and also helping students realize that science is a constant development of ideas, and that it progresses as more thinking occurs.
7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking?
I found all activities beneficial, but really enjoyed the clicker questions with discussion and working with our group to develop reasoning. We were interested in developing reasoning because it was interesting, fun and had value, I need to bring more of that feeling to my classroom.
8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.
Teacher 14

I felt that all parts/ activities/discussions had value. Honestly.

Teacher 15

1. How would you describe what a scientific model is to someone who is not familiar with models? A model is a representation of an idea or concept. When you take an idea and drawing it out, make a 3D model or do a demonstration you help someone expand the level of understanding.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit? Help show how atomic connect to make molecules. Advantage: "touch" the subatomic world through the model and see a molecule. Disadvantage: creates potential misunderstanding about electrons’ role in atomic structure. Kids might think the ball is the entire atomic structure nucleus, protons, electrons and neutrons.

3. What aspects of scientific modeling are important for your students to learn in your classroom? How to make a model that helps others understand more clearly a concept. That there are different types of models and each type has a specific purpose. Models are just part of the learning process. Models expand known ideas and opens opportunities for more questions to arise.

4. The Next Generations Science Standards recommends that students
should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?

Advantages: Revising models shows that learning in a never ending process. That students can learn to change their models as they gain a better understanding of a science principle (or concept). Using models as a spring board for discussion

Disadvantage: Modeling takes a lot of time and time in a classroom is a finite quantity

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?

Critical thinking is a process that needs a lot of practice. It needs to become a natural part of learning to be valued using the triangle model of representation, observation (macro) and submicro helps kids make connections and to ask more questions. There needs to be a strong level of trust for students to develop as critical thinking. Trusting in the process of asking questions and stating the evidence occurs over time. It does not happen instantly.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?

Group Norms for behavior, room layout of tables/chairs etc, ability to revise ideas without making judgements
Practice communicating, having clear rubrics, providing models as guides in helping students in creating their own models or representations.

7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking?

Experiments - hands on activities and representations. Working in small discussion groups questions and explanations of why answers were given as a listener I absorb information - talking occurs as I process a concept I need a lot of time to think.

8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.

None - everything was good - a good balance of activities

Teacher 15

Teacher 16

1. How would you describe what a scientific model is to someone who is not familiar with models?
A model is something that one can use to explain an abstract concept or complicated process by using possibly concrete activity, drawing, formula etc.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What
are the advantages and disadvantages of this type of kit?
Atomic structure is so abstract that students need something concrete to explain chemical phenomena. Advantage—understanding the types of bonds, breakage of bonds, compounds, molecules visually can access understanding of electron sharing and more. Disadvantages are that students think the bonds are actually structural, atoms come in colors, you can make any molecule as long as the connectors fit together, if size (scale) and a molecule has to have an empty hole to be unstable.

3. What aspects of scientific modeling are important for your students to learn in your classroom?

NA
4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?

NA
5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?
One can use clicker questions to engage students in discussions. Analogical models so students can support their macro observations. Drawings at sub atomic level to explain macro. Formulas, electron balancing, Lewis dot representations, etc.

XX X X
6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? Communication can be by posters, oral discussions, drawings, structural models, clickers with discussions, graphing, tables, etc.
7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking? Always be thinking how I can connect the sub atomic to what is observed. I have certainly not done enough of this. Use multiple representations when on a topic or concept. more analogical models for abstract concepts. working on what a claim is from evidence and how you can support it with scientific reasoning. My students are still not good at this.
8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking. Looking at student data was good, but wish we could have gone into more common misconceptions.

Teacher 16

<table>
<thead>
<tr>
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Teacher 17

1. How would you describe what a scientific model is to someone who is not familiar
with models?

A scientific model is something that represents a concept or experiment. A Model can be a picture, graph, table, figure, or physical representation. X

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?

The purpose of using a kit like this is to allow students the opportunity to view a concept in a different way. A drawback can be that these models, while great representations, are not exact representations with respect to size (proportionate to one another) and construct (protons, neutrons, electrons) X

3. What aspects of scientific modeling are important for your students to learn in your classroom?

A model can be any non-text representation of a concept concepts should be represented in multiple different models of communication X X

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?

Advantage - models will improve over time (with proper instruction/feedback) models, when created by groups of students, promote discussion and force students to promote and defend their ideas using knowledge of concepts X X

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking
deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? Picture of Johnstone’s Triangle with (micro, macro, representation) Facilitate activities that involve these and aspects and promote student discussion and debate 6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? Assigning students group activity work that they must present to their classmates and defend their findings and ideas is a great way to help students become successful in communicating chemistry 7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking? The most valuable activity in the chemistry strand was that we were constantly making posters with which to communicate our findings. This showed us not only how valuable an activity this can be, but also provided exemplars Diagram of slippery slime poster 8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking. I would try to cut down on lecture time and include
1. How would you describe what a scientific model is to someone who is not familiar with models? A scientific model or any model is a representation of something that we can or cannot see that is used to help us to deepen or develop our understanding of a concept or idea.

2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit? The purpose of using a kit like this is to give the kids a visual/physical representation of something on the sub micro level - the advantages are that students get to manipulate/use physical materials rather than diagrams - disadvantages may be that it might lead to a simple misunderstanding of bonding as "filling holes".

3. What aspects of scientific modeling are important for your students to learn in your classroom? The aspects of modeling that are important for students to learn are to develop multiple representations to show their understanding or misunderstanding of a concept - use multiple representations/models to make connections between concepts or ideas - use of models as a method of communication.

4. The Next Generation Science Standards
recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models?

The advantages of the used of models (developing, revising etc) is that it allows students to develop a visual method to show what/how they are thinking. As new info becomes available to the students they need to revise their models which leads to a deeper understanding.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities?

Using multiple ways to show what is happening.

Silme motivity with the paperclip model to show cross link etc.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?

develop an atmosphere of support/respect for each other- so that as we communicate our ideas and observations students can

7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking?

I was only here for wed and thurs so the only activity that I experienced was the
elephant toothpaste I think the team work did add value through the discussion of ideas and observations I will take back the idea that Bob had for creating posters - the team presentations with introductions assign roles for the poster completion
8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.

NA

Teacher 19

1. How would you describe what a scientific model is to someone who is not familiar with models?
A scientific model is a way to understand a scientific principal by looking at physical and visual ways. It represents what is happening in the science
2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit?
It’s a great way to show the connection and bonds between atoms of one or more elements. It is tactile, so you can visually see the make-up
3. What aspects of scientific modeling are important for your students to learn in your classroom?
I find that students understand concepts better if they create models. They also look at the limitations of a model as well to help them realize

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Teacher 18

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that sometimes models are not always great at representing a concept.

4. The Next Generation Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models? The major advantages in developing, using, and revising models is to show initial understanding of what it is you are modeling as time goes on, thinking may have changed or understanding may have increased therefore gaining a deeper understanding of the concept. The disadvantage for students is when the hold onto an idea or resist the change of that idea can bolster misconception or a lack of understanding.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? Using multiple ways to show what is happening. Slime motivity with the paperclip model to show crosslink etc.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities? The ability to share their thinking whether it is correct or not is important. The teacher needs to foster a safe environment for students to be successful.
7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking.

I like the collaborative in the poster work. I gathered lots of ideas such as each student creating their own piece and taping the whole poster together (Gloria group's work). I found all of the activities interesting and engaging. I'm sorry that I missed the first day. I'm planning to use journals next year to gather information on student understanding. I want them to reflect on their learning experiences much like what we did here this week.

8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.

The content was excellent, but I don't have a strong background in Chemistry and was a little lost at times although I don't teach chemistry. I found that all activities I participate in were encouraging and I learned a lot of science I liked putting our ideas down on a poster and presenting in a whole class setting.

Teacher 19

Teacher 20

1. How would you describe what a scientific model is to someone who is not familiar with models?

It is a physical, graphical, numerical representation of a phenomenon we can not
2. In many chemistry curricula, students use representations of atoms, such as the atomic-model kit shown below. What do you think is the purpose of using a kit like this? What are the advantages and disadvantages of this type of kit? Advantage is to "see" and understand different atoms are connected some way. Disadvantage is the balls are particular colors-atoms are not. They are the same size-atoms are not. And the force (non physical) is represented by a physical object—spring, stick.

3. What aspects of scientific modeling are important for your students to learn in your classroom? The purpose is to visualize 3D objects
   Hand drawn pictures
   Graphing data

4. The Next Generations Science Standards recommends that students should be engaged in developing, using and revising models. What do you see as advantages and disadvantages for instruction in chemistry of developing, using and revising models? The definite advantage is deeper understanding of the concept and the process of doing science. I'm always concerned about student focusing on doing the "right" model rather than understanding the concepts and not making the connection.

5. Sometimes we want to facilitate inquiry based activities with our students with the goal of thinking deeply about chemistry we can observe and connect it to what might be happening on the atomic scale that we cannot see. What are some of the principles we might employ in our classroom to help students be successful at these activities? All thoughts, suggestions are welcome doing it again.
Sometimes we just don't know and it's ok.

6. Sometimes we want to facilitate inquiry based activities with our students with the goal of helping them communicate chemistry. What are some principles we can use in the classroom to help students be successful at these activities?

All modalities are useful: some may be better for one aspect of the understanding than another. The model does not have to be pretty.

7. What activities did you find valuable in the chemistry SA strand? Do you feel that the teamwork you experience added value? Were there ideas you will take back into your classroom? Please explain using any modes that help illustrate your thinking.

The teamwork does added value, the labs in combination with reflecting collaborative discussion and working on communicating as a team was a valuable lesson in conducting inquiry in my classroom.

One idea stand out for me, although I am sure I act on it anyway, for that the scientific process is not linear.

8. What activities did you find that were not very valuable in the chemistry SA strand? What might you change or eliminate? Please explain using any modes that help illustrate your thinking.

mixing the groups might be helpful. I choose groups in class all the time.

Teacher 20

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APPENDIX 10 INTERVIEW TRANSCRIPTIONS

Interview 1

How did you communicate your findings from your first poster?
If I remember correctly we each time we completed a poster we put it on display and kind of went over it orally and said what our finding were, whether they were what we expected or not. Basically give a mini presentation which is pretty routine.

Why did you choose those strategies?
I think it had to do more or less with the structure of the assignment. It was pretty much what Mitchell had asked us to try to convey.

What changes occurred from the first to the last poster?
I guess it looks as though we went to some illustrations here and here (Posters 3 +4) put some quantitative data in the final one (5) and this one...I can’t help but wondering we had more time to finish this one than we did the others just because there’s considerably more to it.

Why do you think there was that change?
I would say probably because during each of the presentations there was some feedback that was kind of shaping the desired response. You know what the expectations were. How much detail and what kind of detail to include in order to flesh it out and make it more useful to the other groups in the room. It seems like there were three or four other groups that were doing similar sorts of things at the time and then sharing the findings, doing a little expo kind of thing. Remarkably similar to some of things that we do in class with some of the PBIS materials that I use in my classroom but we are much more inclined to instead of taking markers and poster paper a lot of the time I will just have the students work up something on their laptops and then they will plug it into the smartboard. It is that kind of a step ahead technology wise but the content isn’t dramatically different. It is a lot like we are doing there with those little experiments and presentations in class. I think it is a good thing. Since I started using PBIS materials, I hear a lot more of students talking science and they hear a little less of me although they still tell me I talk too much.
What is the importance of this change that you referenced? They are not the same activity or with the same kind of depth of content but I guess the importance of the changes that occurred kind of shaping what the desired outcome was supposed to be. I think we were kind of being led in the direction of trying to convey in a more effective, scientific way. What we had been working on. I think that is the main idea. It was that we were gradually progressing in the direction that Mitchell was leading us in order to try and make the presentations more useful to the other groups, to the observer, to the peers that were in the groups.

So when the posters were being presented you had a chance to discuss your poster and be asked questions. How did that influence subsequent posters? To a certain extent, yeah I think so, you know I don’t think that anyone wants to be in a room like and be the weakest link. So everybody sort of ratchets’ up the output that they are producing in order to stay with the norms of the group and not be leaving out important stuff. I think that everybody was sort of gradually moving in the same sort of direction and I felt that the group that I was in was relatively relaxed and low key and I don’t know that we really. We didn’t seem to have the group think that would have resulted in okay guys let’s get all intense about this and make this were we fill up every square inch of the paper but all in all it seemed as though we were being led in the direction of trying to improve the science behind what we were doing. More or less being instructed on how to combine that presentation and multimedia sharing of our research and our results with other scientists for lack of better wording. One of the things that occurs to me about it you know the content that we were working on might have been a little over the heads of the students I teach chemistry to. Because they are in 8th grade. So if I were teaching high school chemistry or maybe even freshmen in kind of a general physical science that was/ seemed to me like it was fairly high intensity chemistry for 8th or 9th graders. It was fine with all of us but it was limited application. That is what I am thinking you couldn’t translate these necessarily or all of them into things that you can do with 8th graders some of them were a little bit more complicated. A lot of the electron configuration stuff, didn’t really maybe high school honors chemistry but it is not likely to be anything that 8th graders would likely see. They would barely get to recognizing that there is more than one energy level. As far as putting all the electrons together in the orbits and everything, I don’t see that happening. I don’t think that I have ever gotten that far, and when I have it has been an exercise in mutual frustration with each other.

Was the process of making the posters a model? Absolutely, especially the idea of you know being able to visually represent you know some things like the molecular structure. Or kind of structuring the presentation to more or less follow the experimental method or you know presenting some data in the format. You could easily show it to people because an audience by nature so we gain so much information visually that you know that not showing them something has that effect of making us the Charlie brown teacher with the trombone, or whatever it is, yeah absolutely I think there is a number of different ways to look at it being a model or a piece of a model when it is added on to the explanation that we are doing to go along with it.

If so, how did your methods of creating your model change? I guess that the feedback that we could take starting from the first one, the questions or the comments from the group and use that feedback in order to kind of improve the model as it went along to gradually make it more useful to the audience include what they needed to see you know thinking about what we could explain out loud and didn’t need to show on the poster paper and how to make best use of this much space and this much time.

So looking at just poster 4 Focusing on this poster, what strikes you as important in this poster? I think that this one was about the slime the borate and PVA reaction and this is one where what we trying to illustrate is the multiple levels of representing or modeling what was going on that reaction that experiment. We were able to show it at the molecular structure level and the model with the paperclips and then explain it in words and say here is our blob of slime that we made and we can tie it all together.
What are you attempting to convey with that poster? What is the purpose of the poster?
I think it is to be able to mainly show that there are connections between what you can see at the macro level and what is going on at the molecule level with the paperclip model as kind of the go between. So it is nice that it takes you from here is the observable properties of slime and it stretches and it does all of whatever it does and this is really why and if you could see this it would look like that.

How was your role at Summer Academy different than your role as a classroom teacher?
I guess to a certain extent we take on the role of learner’s and these classrooms where you know we are more or less being given an opportunity to learn and being asked to not necessarily act like 8th graders but to take on the learner role more than the instructor and so having much more background knowledge we have I can see where working thru 8th or 9th grade level science experiments might have been a little bit tedious on the other hand we might have been able to go a little bit more quickly and covered more ground.

There are quite a variety of people who teach at different levels and use different kinds of materials but I think that the main thing is that it gives you a chance to reflect on what you do as an instructor as well as kind of see things from the other side of the desk. You know look at as the student would view it if they were sitting there in the classroom and you were to give them an assignment like this. It is interesting that you should ask because I was thinking recently about the fact that I am inclined to start right at the beginning this year by saying this whole standards based thing means that you have to get used to producing some kind of product. You have to provide proof that you have accomplished something for me now to be able to give you a grade on it and say that you have accomplished this or that. That you have met this standard or accomplished this learning goal. I don’t want to see anyone there sitting doing their nails. You have to have a medium for recording what is going on in class. You have to either have a notebook open or a laptop going on so that you at least have the ongoing opportunity to sit there and have some kind of output as well as what kind of input there is. It definitely needs to be actively taking part in what is happening and that is probably a good thing about doing something like this is that there is always the foreseeable expectation that you have to produce something you have to represent your learning some way or other about what you have been up to and kind of take the time and trouble to show it, to demonstrate it, to say here is the evidence this is what I can prove that I now know as a result of been there and done that.

Was that beneficial to have that different role? How?
I guess that is the main one that jumps immediately to mind. I think it was fairly invigorating in a way, the reason that I stick with it is because I enjoy spending time with smart people who do what I do and know what I know and are interested in how to improve on it. Because I thought for a long time there has got to be a best way to do this or a better way to do it. I have always been hoping that someone while I was sitting alone in my classroom trying to figure it out it sure would be nice if someone came along and told me what it was. Save me a lot of trouble so it turns out that everyone has a piece of that puzzle and so it is nice that we can kind of put our heads together and networking the social aspect of it is definitely a plus because it is a really collegial type of atmosphere. Everyone is pulling in the same direction and hoping to improve things for all concerned. That is a great thing about the whole program; we are all in the interest of improving science instruction which is what we all do making some honest strides in that direction. It seems like we have hit upon some good information to have and I like to think that there are some things that have come up upon the way that will show up in the big final report. That will say well we would like to ring our hands and say there is nothing that we can do about absenteeism, or students who are not productive when they are there actually resisting. We kind of have to acknowledge that yes we do need more time yes we do need fewer interruptions and you can’t be pulling kids out of class for school pictures and assemblies pull them out of study hall don’t take them out of science class because for crying out loud when PSP says we are going to plan on you having out of 175 school days we think that you will get 150 class periods in and it is not necessarily so. It is bizarre for something’s that.
they get dismissed early for they come in later. Or are called out of class, now we are 100 pages behind the pace and it is memorial day so what are we going to do, we can only squeeze it just so much before you aren’t having any effect at all

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Interview 2

How did you communicate your findings from your first poster?
Well it looks like we even had a section that says summary of findings, and so we made a bulleted list of the data that we collected And so it looks like we made observations of if the cans floated or not and other relevant information that we thought might be important in trying to reason our claim So that the volume was the same for all four cans that the mass was significantly higher for one of them and that the density was higher Why did you choose those strategies?
The strategies of looking for volume or for communicating the findings? Ok.
I think that we were trying to communicate any information that we found that we thought might be relevant because we, I am not sure that we ever found good reasoning for the final results that, of our findings and so I think that we were trying to put any information out there to the community that maybe could help us with finding our answer and so maybe the density wasn’t telling us enough information. I think it probably was but maybe it wasn’t giving us enough information and if we put out there maybe somebody else would pick up on that and start piecing some things together . Some of the information that we initially communicated was really, like all the information we had, but we thought that it was still relevant we had some idea of why the pepsi sank and why the others did not but I am not sure that we were all, that we had the same conclusion.
I was a little more skeptical, I thought some other things were happening as well. I wasn’t confident on our measurement techniques and so, I wasn’t convinced yet

What changes occurred from the first to the last poster?
I think we definitely became more focused, putting all the information could out there
I think we became a little more targeted and I think that we spent more time with our conversations before creating our posters and really

Elements

How did you communicate your findings from your first poster?
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I was a little more skeptical, I thought some other things were happening as well. I wasn’t confident on our measurement techniques and so, I wasn’t convinced yet

What changes occurred from the first to the last poster?
I think we definitely became more focused, putting all the information could out there
I think we became a little more targeted and I think that we spent more time with our conversations before creating our posters and really
planning out what should go on our poster, but also what is the reasoning. Reasoning is obviously missing from our first poster and we spent a lot of time discussing reasoning, by the time that we got to step 3. It is not on the first or second poster.

I think through discussing the reasoning I think that we could better decide what findings to put on our poster there is no reason to put all the information you found, every observation that you made If it is not really relevant to the claim that you are making or the reasoning that you are providing, so I think we became a little more targeted in the information that we wanted to communicate.

We also have a procedure here which we didn’t have before, we kind of put information into the findings, that was really just part of our procedure and so it kind of had it’s own section. By the time we get to the third poster Even our organization of how we put each section on our poster was much different and I think that it was purposeful that we changed how we organized information. By the last poster I think this question was a little different that we were exploring and I think that why it looked different from three and I think this was more trying to work through some bigger conceptual ideas of why this thinking helps us and helps our students and so that’s why four looks much different than the rest.

Why do you think there was that change?
I think that we better understood what our goal was in mind. In the beginning, we weren’t really sure if there was a certain way that we should be organizing our thoughts.

So I think that’s why it, more information finally got onto the last poster. If you look at the beginning, it kind of the paper is filled up, but because we became more targeted we were able to also provide more of our information from our discussion. We decided what is important onto our poster, like the reasoning. Where before we kind of just trying to put basic information that we thought we needed to communicate but I think by the third poster we are really trying to represent more of our conversation and we had a better understanding. I mean these are different concepts I guess but I think that we had a lot of detail and maybe even more curiosity too with the slippery slime than with the others. So we really weren’t digging as deep into them because it was a can and it sank or it floated and I think that some people had already done the experiment before too so it wasn’t as intriguing as the slippery slime And trying to figure out what was going on with them and having multiple models to I think you have to be able to represent all the information at once so we decided what is important onto our poster.

What is the importance of this change that you referenced?

NA

So when the posters were being presented you had a chance to discuss your poster and be asked questions. How did that influence subsequent posters?

I think that is why we did put our reasoning because before I mean the questions that were asked. I am not sure that we had even discussed either so it is not just that we didn’t put the information it is that we didn’t even discuss our reasoning so by the third poster we knew what people were going to be asking. We knew that we needed to be communicating our information well so I think that is why we now have charts, data tables, and less of just the overall data collection.

It was like I said it was really targeted to just the important information because we really knew that’s all the other groups needed to see too. They wanted to know that there was some reliable procedure so we included it and to help them understand what the information representing but I think that I think that is what caused the change.

Was the process of making the posters a model?

Was the process of creating the poster a model? It fits the criteria I guess I really haven’t thought about the process being the model. Because we were revising our ideas often and I felt like by the third poster, fourth poster we were modeling more often to each other creating drawings, diagrams and trying to show each other like I think this is what is going on I think this is what is going on I don’t know if it is a model, I guess, but I know that we definitely used models but revising our ideas and creating the posters we have some representation to communicate if it’s the criteria.
If so, how did your methods of creating your model change?

Definitely having a better understanding of what was expected and not to say that anyone corrected you and said you should have had this and you should have had that

Even using that the terms claims, evidence, reasoning. I think that we had to kind of feel that out to see okay that is kind of the language we should be using there that is how we should be organizing our thoughts I am not sure that we had organization in the beginning. I think it almost felt a little lab report style in the beginning. You know. So I think that as we started to use that language more it started to direct how we created our posters and how our conversations went to because we knew that we needed to be hitting on each one of these points.

So looking at just poster 4 Focusing on this poster, what strikes you as important in this poster?

And the poster is very different because we weren’t using that question claim evidence reasoning. It was we were trying to create something visual to communicate with others that didn’t really follow any format. It was really just a representation that came from us, but we were obviously trying to incorporate different ideas that we had collected throughout our process

What are you attempting to convey with that poster? What is the purpose of the poster?

This is the sub micro, macro, representation poster. I think we’re trying to show how all three of these are not just separate that a representation can be macro or micro and so we were trying to understand how their similar and how these things are different. We actually had trouble with this conversation because we weren’t really sure of how we were supposed to be discussing this information because we felt like we answered the first part of it about students or maybe it was about teachers first and then the second question came up and we said it is all the same.

So I remember having a lot more discussion as we went through this but this was more of a brain storm but it was collective of all of our ideas but it wasn’t trying to come to some conclusion like this one was. Where you are collecting evidence, this one was really just our ideas we were trying to represent

How was your role at Summer Academy different than your role as a classroom teacher?

– I think that I definitely in a group where I am not certain of the information. It is a very different role, obviously where I think I was doing a lot more listening than I maybe do in my classroom, which was a realization for me because maybe I should be listening more.

Working within a community and this was very uncertain to me. Even what we were doing was very uncertain and so I think in the classroom you know where things are going

You are trying to lead them to some certain place and so it is very different, to be led. I think.

And to be led in a way, like with Mitchell, that isn’t like he is looking for you to fall in one place.

I typically have in mind, it seemed like wherever we end up is where we end up.

It is just very different I guess than being in your own classroom as a teacher

Was that beneficial to have that different role? How?

- I think it was very beneficial even to see how Mitchell leads his classes, and I don’t know if this is what he does in his own classroom.

But to have that type of experience helped me to reflect on what I was doing in my classroom and am I allowing them to be creative and giving them kind of an open question that they can explore.

I don’t think that I do and I thought that I did, but I don’t think that I do enough that these types of genuine conversations can come out.

That a community gets to help you revise your ideas and critique you, but that in the end you are not told if you are wrong or right.

And that I think eventually in my classroom I do try to come to a conclusion that you know even at the end of a class I don’t think that I let it linger a few classes.

I think that I always try to make sure that things are cleared up before they leave, and this was very different.
Elements

**How did you communicate your findings from your first poster?**

Give me a minute here. We basically just did it by writing a claim and gave a statement of evidence gave no charts, nothing else

**Why did you choose those strategies?**

Well I believe our directive was to state a claim of course we stated that in words and to give evidence, but when we gave evidence, I think we just thought it was a general we weren’t into a nice detailed poster. Cause we say we calculated density but we didn’t go ahead and give any chart of calculating it. It was poorly done.

**What changes occurred from the first to the last poster?**

We got so much better. The first to the last. The last one really wasn’t the same idea. It wasn’t an experiment but if we look at our three things where we are actually doing some kind of inquiry of something. We added drawings, we often showed our calculations, we gave a chart, we stated our reasoning. We went from doing claim and evidence to where we did introduction, purpose, procedure, results, claim and reasoning. We got much more detailed in our reports

**Why do you think there was that change?**

NA

**What is the importance of this change that you referenced?**

Well I think that if your, what we are trying to emulate was if you were in a scientific community, how you communicate scientifically to others and I think that we learned that you had to do it multiple ways and make sure that you gave detailed procedures and reasoning for someone else to understand and duplicate your experiment.

**So when the posters were being presented you had a chance to discuss your poster and be asked questions. How did that influence subsequent posters?**

–We added a lot. When we saw that people asked questions about our procedure or they asked questions about what our calculations were. What apparatus we used. Cause in the second one we actually did drawings of the apparatus that we used. And the third one we did So there feedback, we took to heart and we tried to make it much more detailed. So that they would understand exactly what we had done.
Was the process of making the posters a model?
That is a good question. Maybe a part of it. Like we may have modeled. We did the reactants. Proportions of reactants from when we made slime We made drawings of what we thought was happening and I would call that a model of the activity. I am not sure that I would say the poster itself was a model. Ideas and creating the posters we have some representation to communicate if it’s the criteria

If so, how did your methods of creating your model change?

NA

So looking at just poster 4 Focusing on this poster, what strikes you as important in this poster?
This one I might say is a model. Cause we were to define sub micro, macro and representation and how we would move from each. We modeled triangle the movement and discussed in more detail each one
What was your question again?

What was important?
Just looking at that. The movement is not static it is dynamic. Go from the macro to the sub micro and then some kind of representation analogy of it.

What are you attempting to convey with that poster? What is the purpose of the poster?
I think trying to show, you want to combine those three for a greater understanding. You don’t just stay in the macro, when you are talking about chemistry. You have got to be able to move them to the sub micro and have some representation of it.

How was your role at Summer Academy different than your role as a classroom teacher?
I got a different perspective, I got the perspective of the learner. Which was great.
But it also was eye opening because our first poster we thought was okay yet if I was the teacher I would have said what “that is terrible”

So, I think it was when we started to do our second and third we really were starting to think, okay as a student what do we think is important to put on there and then also come back as a teacher and think about how I would critique that

Cause we were critiquing others, so we got both perspectives. Instead of just teacher perspective. I hate being the learner. It is not easy.

Was that beneficial to have that different role? How?
Oh, yeah. It is just really frustrating because you have done so much of the one side to go back to put yourself back in that. It is an uncomfortable feeling. Of not being sure of exactly what is being expected of you. And then you remember that is how your students feel when you are not. They don’t understand the topic or they don’t understand your directions or whatever.

It was good to be able to work with others though. I would hate to have a classroom where I would be on my own. So that helped me also think about setting up my classroom to make sure that I am always at least pairs and if not pair to pair so there is a foursome.

Interview 4

Elements
How did you communicate your findings from your first poster?
We communicated with qualitative and quantitative but looking at our quantitative result it was still kind of more towards the qualitative aspect there weren’t any numbers. It was kind of suggested that we have taken volume and density and mass measurements but our report didn’t show any of that.

Why did you choose those strategies?
I would say that we choose those strategies for time sake, because it is much more easier to take a quick qualitative assessment of something and then go back to your class and report everything out versus taking the time and measuring everything out individually and then reporting that back because we definitely seem to have a time scale for the training that we need to commit to so maybe that was in the back of our minds while we were doing this stuff.

What changes occurred from the first to the last poster?
Well right off the bat it seems pretty clear to me that our presentations became more elaborate as time went on and therefore our explanations were more complete. There didn’t need to be a whole lot of question once we got to our final kind of poster here. Whereas in the beginning that begged a lot of questions in our first poster.

Why do you think there was that change?
I think that part of it was that we got use to working together as a group over time so we were more able to effectively communicate our ideas and decisions suggestions cause we were there for four days. By the end of the last day we really kind of had our act together as far as what we wanted to put out but that was also a result of group norming with the rest of the chemistry cohort because it wasn’t that we just were interacting with each other when we were doing this we also were seeing what everybody else was doing and there was definitely that trend towards more elaborate and you say there were attachments off to the side but it was definitely a trend towards a more complete and extensive explanation of the different activities that we had completed versus just a very brief cliff note summary became more into numbers and models.

What is the importance of this change that you referenced?
From a scientific perspective it is important when we are doing experiments to have move complete explanations because if someone were to come along and challenge the experiment they would want to be able to replicate the procedure but without a complete explanation you can’t really replicate the procedure cause when you look at our last one (5) we have a very clear Trial one two three. This is the volume of this reactant this is the volume of this reactant here are our predictions our evidence whereas with our first one it was they floated so it is pretty difficult to gauge a measurement of they all floated versus specific numbers. When we are talking about replicating experiment.

So when the posters were being presented you had a chance to discuss your poster and be asked questions. How did that influence subsequent posters?
It made us want to deliver a better product because when people asked questions they generally don’t ask me about why you chose that awesome color and to do this. They ask well how come you don’t have this on there or why didn’t you explain this aspect of your experiment.
and so with that in mind you think to yourself well then in our next poster I have to take that into account, I have to explain that as well. So I mean that was the other aspect the feedback was continuing and eventually, I bet that if we continued for a week you would have seen some seriously elaborate and very complete posters.

Was the process of making the posters a model?
Yeah, making posters is a model but there is also models within the poster model. I guess because you have, for example in poster 4 we had very clearly two models right here this representation or model is just kind of a rough drawing of the polymers and monomers and how we assume that they would bond and then this model is of the exact molecular structure of the different molecules and even some hydrogen bonds going on over here so those are two representations on a representation. So it is models within models.

If so, how did your methods of creating your model change?
It was once again more trial and error. When we present to a group we would have something like this which is a basic column (table) and we were asked more question and so in order to answer those questions before they were asked we would add this other more elaborate drawings and measurement here and here. So that is was kind of like building a car and then just messing up over and over again and learning from your mistake and eventually your car get better.

So looking at just poster 4 Focusing on this poster, what strikes you as important in this poster?
What strikes me about that’s very important about this poster is are you talking about very specific to this experiment? Well for this experiment it was the goo. Whatever it was the slime. This was our paperclip analogy this drawing here with the little loopies bit in actuality that molecular drawing is actually what it is and so it allows people who are reading this poster to understand okay well this is what this is the experiment that we did and we bonded these two things and then if we actually wanted to know what it looked like it’s this and you can kind of see when you are looking at it that if you kind of cover up that bottom chain right there that’s pretty much what that is so it visualized that analogy.

What are you attempting to convey with that poster? What is the purpose of the poster?
That the sodium borate is a linker for the poly vinyl alcohol. So what we are trying to do here is take this phenomena and give you a real world example of what it could be.

How was your role at Summer Academy different than your role as a classroom teacher?
Well as a classroom teacher you are alone that whole aspect but your not really subject to as much criticism by your students and your peers. I guess when you are a teacher you are alone in your classroom. I mean you will have people coming into observe you and give you feedback but the constant feedback that was delivered here to me and as a participant in summer academy definitely change the ways I did things. For the better, as far as proper products were concerned.

Was that beneficial to have that different role? How?
Yes it was because you know it kind of refreshes the idea of what it is like to meet new people and start to work together in a group of people that you don’t know and what it is kind of like to pitch new ideas. Because then that give you, it reminds you of the perspective that your students are going to have when they walk through that door in two weeks they might not know everybody, it is going to be a new situation. You know I am going to be a new teacher and so they might be nervous or shy or goofy. It is important to remember my perspective from when I was doing this to help kind of steer them towards the science that we are going to do.
How did you communicate your findings from your first poster?
As far as multiple modalities we only used words, we did it in essentially single sentences. Even our evidence its qualitative expression of what we did, right. So it says calculated densities but there is no actual evidence there. Were more buoyant but no numerical backing up of that. And no reasoning right that whole claim evidence reasoning thing. I am trying to recall the summer and I don’t but it seems like we either hugely rushed or we were clearly not thinking about all of the different elements we could be using to express what we had done.

Why did you choose those strategies?
I don’t have a precise recollection but I would say it probably it was like I want you to make a poster about what you found out and all of us grownups, all of us talkers in the room were like okay lets write some stuff that we did. None of us talked immed iately about drawing pictures. So it was like you want us to tell you what we did so this is what we did and we are going to tell you in writing with the same words that we would use coming out of our mouths. And I think it actually is conversational, we basically just scribed probably like one of us looked at another and said you know they were more buoyant. They all floated and were like okay. So I think that is why.

What changes occurred from the first to the last poster?
So obvious, right a blind man would see changes. So we gave a title we gave some context. We used graphics we tried to visually represent what we did as well as sort of prettifying it. We have different fonts and little highlighted kinds of thing, like eye catching drawing attention to different things. We included things like procedures and materials and I see as we move through that we have data table, we have no only included illustrations but we’ve captioned them, we labeled them with figure number and referenced them in our writing. I remember doing this last one and then this one was about sort of our experiences as opposed to doing a lab. So we didn’t do a lab and the represent it, instead it was how do you think you have done this week. Wasn’t this more reflective.

Why do you think there was that change?
The macro world the submicro world and representation. Basically this was reflecting upon all the experiences we had up to that, and so you would expect there not to be lots of data necessarily and not illustrations of practice but we still managed to work in more visual representation than we did in the original. So even though it is heavy on the linguistic there is a lot more of it there is a lot more writing. Our writing is more explanatory. So it says to make the connections we need to do this and it is very hard to do that so we are actually explaining our thinking rather than just stating something as though that is the way it is.
What is the importance of this change that you referenced? Wow do you want to cover all of the importance from a visual perspective, a teacher perspective a learning, all of them after the first one are a lot more informative and communicative. Even if we were wrong in our thinking, even if our outcome was wrong, even if our claim was wrong it is so much easier to understand why you are claiming what you are claiming when you are taking the time to explain all of your thinking when you are including descriptions of what you did to arrive at those things. So not only our reasoning but our methodology and how we got to those things. Providing the underpinnings providing the data that led to you know to those. Thinking about it as a teacher if these were my students the first poster you might give it a 100 or a 0. It is like you are right or you are wrong. There is nothing formative here, it is kind of a summative assessment. It is all you could think of it as. For all of these other ones, it could be formative, it could be summative, you could have so many individualized conversations. This would help me tweak my mini lesson, you would get enough information from a single poster like poster number 3, to think wow. I can break down all of the components of an investigation and say that this group here. They got this part and this part, not this part, they got this part, I think that we did a great job with number 3 because we tried to cover everything. So from the perspective of the teacher, I think that what I am seeing is that the multiple modalities they help me see what students are thinking. I think they students represent their thinking better I don’t know if this was the case in our group necessarily so I feel that I am abstracting a little bit from experience but I am looking at some of these illustrations and I am thinking of my student. Like asking my students to write in a paragraph what they did, it is like pounding my head against the wall. But asking them to draw a picture of what we did. I might be able to see that is what you did. I totally understand what you are not able to verbalize because I can see it pictorially. And so I don’t feel like anybody in our group, I am the who drew pictures and I don’t feel like I drew them because I couldn’t articulate it. But I feel like that is a big component when I look at a poster like this and I say oh this is another way that these people are showing me what they did and what they learned through it.

So when the posters were being presented you had a chance to discuss your poster and be asked questions. How did that influence subsequent posters? To some extent yes, I think that my recollection is that everybody’s first poster was kind of meager. Our poster was exceptionally meager but as soon as you get that public arena. We all wanted to look good, we all want to look good in front of our peers. So there is that pressure there. But I don’t feel like we saw amazing posters and then we looked at ours and were like wow we really need to step it up. But it was more like wow our presentation was all but 13 seconds long, we read 2 sentences like we really didn’t communicate anything. And so part of the experience was that we made a poster but we didn’t really communicate what we did and why we did it and why we think we now have learned something. Why we now have a claim and so for me maybe it had something to do with the whole audience thing but I think largely it had to do with the wow presentation wasn’t really a presentation. I could have sad that sentence from my seat.

Was the process of making the posters a model? That is a really hard question. Is it still the same question if I change the wording a little bit? Was the process of making the posters modeling? I think of process as a verb.

If so, how did your methods of creating your model change? So my gut reaction is no this not modeling, because we are not trying to represent a phenomena. We are trying to give information about something that we did but that to me is not kind of the same thing but hearing the sub bullet. It’s that we were trying to take what is in our head and represent it in a way that is clear and communicative for other people. We all know what we did at our table, we talked to each other about it. But no one else in the room knew. They had all done similar things but nobody knew what it was we thought about it and so as I look at the evolution of the poster and I sort of think about them as modeling. What we did differently is that we working a lot harder to pull out all the stuff that was sort of subtext. All the in between the lines stuff. We were
like great you thought that but why. What we tried to do was make explicit all of the thing that led to our final ideas. I think that part of it had to with Mitchell. With him sort of saying, I see that first attempt that is really interesting but what about this and what about this, do you see that. He really sort of opened up into the whole room like. Why is there a poster presentation, I am not really thinking of you guys as 12 year olds. I am expecting you to do what I see at conferences. That is sort of the impression that I got. Wow he asked us to do a poster and we gave him three sentences. Well 2 and a half sentences. So I think that a lot of it came from me thinking about expectations. Here there is a renowned university professor, an expert in his field a man who has seen countless poster presentations. He has clearly go a benchmark, he has an expectation and we didn’t come anywhere near to meeting that and not like that was an unfair expectation but this sample 1 is no even acceptable from a 12 year old. It was a combination of those things.

So looking at just poster 4 Focusing on this poster, what strikes you as important in this poster?

Well right away it is the triangle, for me I love that model. That model has not left me, I had never seen it before but it absolutely hasn’t left me. A couple of weeks ago I was here for summer work and someone kept using the word micro the micro realm. I was like the sub micro realm. Cause I can’t see atom with my microscope and immediately I was thinking about this. I was going back to this, there are the thing that we can see and the things that we can see with tools and those sub micro. Where they are so small that you microscope isn’t going to cut it. So for me when I look at this poster it is that there are paragraphs everywhere there are words everywhere there is a little exploding bullet showing our calculating chemical formula but for me it’s I see three different things. Three different phenomenon’s, three different domains, three different whatever they are and the fact that they are all being connected in some way. This helps me, this gives me a framework, everything I am about to read on this poster I going to think applies in some way to connecting those dots. That it is going to connect those three realms in some way.

What are you attempting to convey with that poster? What is the purpose of the poster?

I think that we have some disparate features here, but I think that the main idea here was that having students think about everyday world and then learning new concepts like the sub micro like chemistry stuff. That is applies to the larger everyday world but the only way those connections are going to be made explicit is through representation. Because we can’t give them an atom to hold we can’t give them an atom to see. And so in order to make sense or how does what I see relate to all the stuff that is so small for me to see. It is all about how they are going to be representing that. How are we going to be representing that to them. How are we going to use their representations to gauge their understanding. That’s what I think the main idea of the poster is. Even though saying things like students are more engaged when they understand deeper. It is not really about that, it sort of supports it. That is the main idea for me, connecting the three points of the triangle.

How was your role at Summer Academy different than your role as a classroom teacher?

Mitchell definitely gave us opportunities to speak about our experiences but even in that role I still felt like a student. He was doing what I do in my classroom, saying hey we are learning this new thing who know something about it. My kids raise their hand and say at my house blah blah. And then Mitchell asked a question I would say in my classroom blah blah. I felt for that week very much like a student. However I did not feel like there was a sage on the stage. I didn’t feel like even though I knew Mitchell knew everything that I wanted to know. I didn’t feel like there was the guy hordling all of the answers. I really felt like an adult learner. I felt like an adult student. But I absolutely felt challenged. And I felt I knew way less that the guy who was running thins. Which is obviously true, and I was really focusing in on my own learning. There is so much that I don’t know about this, I need to feed my knowledge here. Because there is so much that I don’t know. I felt like a really eager student, which in a a sense is what a teacher is. We are really eager to be learning more about our students as people but also more about what they think and how they think because we want to be assessing their learning and our efficacy. So I feel like as a teacher I am a student everyday but it is a lot more minimal than all of the paperwork and telling people to be
quiet. All of the teachery things we do. I didn’t really have to do any of that. I was like 100% student for that.

**Was that beneficial to have that different role? How?**
Absolutely I think that if that week had been framed as look I know that you have all taught chemistry before I know that you know chemistry so we are going to talk about the way to teach chemistry. It would have been a lot more boring and I don’t think I would have learned as much but for Mitchell to go through it the way he did and structure it so we are being asked to behave like students but at a much more rigorous level than we are asking of our students. It gave me a really good sense of remembering what it is like to be put in that position where you are asked to do thing that you don’t know how to do and you are being asked questions that you don’t know the answers to but you know that you are being give the tools to get there. So I felt that it really helped me identify with my students. I felt like it helped me learn a whole lot more fact that we were put in student groups, we had all these different brains to pick. That definitely helped. We were sitting in rows and desks, when we were trying to balance chemical equations using electrons without Beth and Clint I wouldn’t have gotten them on my own. I would have kept making mistakes, but getting their input. And giving my input to Beth I really felt like we all arrived. I felt like there was that social learning element, and that is so powerful, I ended up learning more than I could have learned on my own.

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**Interview 6**

Elements

**How did you communicate your findings from your first poster?**
We did a bulleted list, you know. We made a prediction. Then we said what happened. Then made a claim based on what happened.

But we didn’t get what we thought was going to happen. I still think there was something wrong with the experiment. Just saying, it’s all good. It was interesting. We could have done it differently, but none of us are that artistic.

**Why did you choose those strategies?**
Because it’s linear. I think we’re linear. So we thought we can do this and do this and do this and then this (referenced the 1st poster bullet) Similar to other outlines in other science class maybe we have been in or
had or taught or you know all those things

What changes occurred from the first to the last poster?
We got better. That is what I noticed. I noticed everybody got better. Wow everybody’s getting better. We tried to draw more. Cause we were talking about that. And so we were trying to incorporate. I drew this one here. We also tried to take turns so that you know everyone had some experience doing some of the work involved. Some of them we all added a little bit of the work to. We tried to show have more visual in them. As we talked about it. And give better examples of what happened. That’s what I remember.

Why do you think there was that change?

NA

What is the importance of this change that you referenced?

NA

So when the posters were being presented you had a chance to discuss your poster and be asked questions. How did that influence subsequent posters?
Well by the end, even this third one is good I think, so you know this one is alright (poster 2 referenced). Density there wasn’t much else to do I think. But these guys write so much neater. So these ones look a lot better. Of course this one wasn’t bad. If one of those guys had written this one it would have looked better. Once we understood, part of it was understanding what was being expected, or what was desired. Even when you was other people’s poster too was part of it. You would see what someone else did and say “oooo” that looks really nice. So next time we will try something like that. Not that exact thing. We talked about using graphs. It’s different than the last using some formulas to demonstrate not formulas but diagrams to kind of demonstrate what was happening chemically.

Was the process of making the posters a model?
Well I do think, you know. I don’t think the first one was much of a model. Cause if you look, I guess it is a model to some degree but basically only model we just used words to say it. To some degree people will argue it’s a model, it’s not a good model. But since we use it a lot. We grow up reading; everybody knows how to do it. But when you can see some times, so if I can see what that means or it I could see the example of you know what was happening when we mixed things or if I could see the examples of what we did there where the paperclips on the poster we could of drawn them too. That shows what happened. It’s a better model. Did I answer your question?

If so, how did your methods of creating your model change?
We wanted to show it better and we were asked to show it better so and by looking at other peoples and by thinking how we could show it better we did and the graphs I think the graphs representations there not models so to speak but their visuals so people can tell what happened without reading a big long boring sentence.

So looking at just poster 4 Focusing on this poster, what strikes you as important in this poster?
Well I think the biggest thing is that we showed it with the paperclips is the biggest representation or the best of what was going on and how we were going from the micro to the macro and how that would help our understanding. It really takes it all to go there. This is what you see (paperclips) the slime you saw this stuff you can’t see (molecule) we see it on the paper. You can see it on the paper. We wrote these things as a model, the little letters, but what’s happening you can’t really see how they you know these things are forming so this model here can help us understand that model here and how we understand this model is by doing the slime and seeing cause we thought I remember thinking it wasn’t that poster it was the poster before we thought that all the groups. I think thought that the slime would be runnier if this happened or thicker
but it actually was runnier it was weird again unlike the diet coke we were wrong The diet coke I think that was wrong this one all the groups were wrong like I didn’t think that way So when we make the models you can see what happens better than when you don’t make the models

**What are you attempting to convey with that poster? What is the purpose of the poster?**

NA

**How was your role at Summer Academy different than your role as a classroom teacher?**

Well cause you’re the learner, you learn as the classroom teacher too, though but the difference being that one way your more facilitating other people to learn maybe how to make a poster like this. It’s kind of funny cause in my classroom I would say you know you got to have pictures on there, you got you know and then we made our poster it’s like nothing you know

Why did we do that – I don’t know – being a student and learning about it was what I saw as my role there although we all contributed to the discussion.

And the everybody there had at some level learned this once before or some of it anyway and so it wasn’t like we went in there blind really It definitely helped to see it at a deeper level it was really I wasn’t expecting it to be quite so good

**Was that beneficial to have that different role? How?**

Oh yeah, that’s why I like going to collaborative or whatever it is I am doing in that role, because I take that direct experience and I put it into my classroom

I say what was it about that that was interesting why did I like it how did that help me to learn it better and I can take that stuff and I say if I can make it like that then my students will feel that way too.

Of course I need sometimes it is a little different because they don’t want to learn like I do but some of them do so you know

It works I take those experiences if I get to use the materials or even at a higher level we made slime in my room and I don’t expect my kids to do (chemical formula Poster 4) but I do expect them to know this (slime) to do that and to create their own experiment and to communicate what they learn

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**Interview 7**

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Elements
How did you communicate your findings from your first poster?
Did they float something in this?
• they put two cans of soda.
They were closed cans. I didn’t do this particular, but just as they did. So, how did they communicate it? They picked a, they made a prediction, of which can would float and which one would sink and then they performed the experiment. Apparently. Then wrote down their findings and then made a claim that the density of the pepsi was greater than the density of the water and that is why the pepsi sank.

Why did you choose those strategies?
I think it’s because this is the way it was all setup that we talked about making predictions and doing experimentation and they followed a process.

What changes occurred from the first to the last poster?
As the week went on, I believe that we became more cognizant of how to setup questions and provide the evidence and make a claim. So I think the progression as the week went on after discussing, because there was a lot of discussion of these in the groups and then outside the groups that caused these to increase and be better as the week went on and show better models. Better understanding of what they were doing.

Why do you think there was that change?
NA

What is the importance of this change that you referenced?
I think it shows a better understanding of what they were doing and makes it clearer to people that are looking at it from the outside. So, a lot clearer, a better understanding, it shows more detail.

So when the posters were being presented you had a chance to discuss your poster and be asked questions. How did that influence subsequent posters?
Well I think what happened is, as time went on people looked at them and they just got more detailed because the discussion got richer and as the discussion got richer then I think the information that got the posters became richer. As time went on And I think everybody, a lot of the sharing people got to see other things and then as they became more knowledgeable it just kept going. More Complex

Was the process of making the posters a model?
The format changed, it had more of a organized, it was more organized as it went on Cause the slippery slime model became more organized with the question and the claim and then the evidence and the reasoning. Where on the first one it was more about the question and the prediction and the findings and then the claim was at the end instead of at the beginning. And then the second paper was really just basically data

If so, how did your methods of creating your model change?
I think from watching the discussions and then watching everybody present I think was a big factor in that as people were presenting people you were noticing what other people were doing and some of that went into that and then everybody was trying to make their’s better It is always that little bit of competition

So looking at just poster 4 Focusing on this poster, what strikes you as important in this poster?
There is more science on the poster. I mean the piece behind it like the chemical formulas for slime, PVA and sodium borate. And I think this is the one where you had to go from the three different types, go from the macro, to the sub micro and then show a representation of it.

What are you attempting to convey with that poster? What is the purpose of the poster?
Show the science behind the slime, why it all reacts together. I mean I am not a chemistry person but if you look at the formulas and you can convey where they are here and then look at them in another representation. They kind of correlate with each other. Kind of I guess they do correlate with each other.

**How was your role at Summer Academy different than your role as a classroom teacher?**

Well this year my role was more of a student than it was a teacher which was kind of nice because I choose to do chemistry because I don’t have a big background in chemistry so I wanted to learn something because the way the format was this year it was more about learning than it was me teaching. So I got to be a student, which was kind of nice.

**Was that beneficial to have that different role? How?**

Yes because for instance chemistry is not easy for me because it is something I haven’t done in a long time so it kind of gives me some insight as a teacher what kids go through. Thought processes and the things that they do and that they go through which in return helped me be a better instructor because you can kind of see those things and think well I know earth science why don’t they know it. When I look at this, I didn’t know this, so I should be more thoughtful when I am instructing. More patient with some of them that don’t get it right away.

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**Interview 8 and 9**

**Elements**

**What aspects of the summer academy might benefit other teachers?**

**Did the summer academy impact you as an instructor?**

1- I would say yes because what you did is you modeled the claim evidence and results model and I took that back and that is exactly what we are doing in our classes at least I’m doing in my class. It didn’t have to be just Chemistry, it transferred to all classes that I was doing. So, being able to walk through that as a student helped me realize the parts of it that might be more difficult than others, also might have doubly helped me in the progression. Because you started out with just the claim, and then you moved on from there. And knowing that even that was difficult to get the claim and not thinking that I am going to give this to my students and they do it all at once. Looking at the sequence that really helped me a lot.

2- I would echo everything that Beth said it definitely impacted me; it
definitely had me focus on the claim, evidence and reasoning and how I would present it and how I would talk about it. The one thing that I would add is that the whole experience of doing it through the model of poster presentations really impacted me. It made me up my game in expectations for students and how explicitly I taught things. I actually replicated in that I asked for a poster and had them produce such squallid crap and then broke it down and we looked at it compared to real posters and we looked at different parts of them. Many of them had the same experience that I did, where they were embarrassed. They were like what was I thinking. I have sent you an email of a picture of the posters that my students created. That extended activity of the slime lab, I did it, so after we were done with SEPUP we did the extension where the kids got to come up with ideas about changing ratios and then I had them make posters about it and I used that claim evidence reasoning framework as the structure for the posters. That is what they were focused on.

As I listed to use the word squalor, that is so great, I think that is the kind of thing that if we can write a little bit about this for the paper it would be wonderful.

1- One of the things that Bob Clint and I were doing for the first time and all you asked was the claim, I have to admit that I was really surprised that we had teachers there and experienced teachers and good students at the University and many people couldn’t come up with a claim. And yet you think that we are asking students 6th 7th and 8th graders. We’ll give me the claim? At least give me that. And we are not thinking that is a difficult thing to do. Focus on what exactly on what we are trying to do here. And we saw even teachers couldn’t do it.

Have you seen impact on other teachers based on excitement from what you are doing? Have you seen this escalating into different disciplines or other classrooms or is it still primarily in your class. Have other teachers observed you or the products that have been made in your classroom had an impact? Have you impacted other individuals in your field?

1- We did it as a science department and we have talked about this because we felt that this is the most important thing for our students to come out with. So we have shared our students’ work together. Kelly Littlefield is doing it as I have left. And we know have two more staff in science. Both Karla and I have left. That became a very important point for us. Kids could not do, could not come up with a claim, could not support it with at least three pieces of evidence and then explain it with scientific reasoning. We felt that we were not doing our job.

2- So I am a science department of one. However, through the leadership academy those of us who are doing the second cohort who all wrote grants and are doing grants. Beth and Melissa did a grant about study group and so I have been talking about my experience through the summer academy and then sharing like the picture that I sent you and I posted on the group google hangout. So I have been sharing my experiences in how it was for me in the classroom with the people that are in the study group.

Did the experience of Summer Academy modify your instruction? I am aware that you have spoken about the posters is there any tangential modification that you can think of, there may not be any?

1- I think that my emphasis after going through it realizing that we really had to exclusively go over claim, explicitly go over what evidence is. You know break it down. We started off with PBIS where we had to put it all on a poster and it had to be done; we never talked about it or broke it down before we got to it. I was disappointed because I didn’t get much well, I guess what I wonder why. I was asking too much all at once. So I think it is thinking I have too much all at once, I have to explicitly work my claim and then we have to go to the next step and not think, even though our publisher thinks that kids can do it all at once.

2- So ditto, breaking it down and being explicit. I will add the same thing where, I loved the model. So often in teaching is that we
scaffold for success. I’m going to give baby steps and then a summative is expected to give us grandeur. The poster experience it changed that. I’m going to sink three whole days into producing crap and then analyzing that crap and breaking it down and saying why is that crap. It was worth it. Not giving them the extra time to show them the exemplar and say hey make this. Prove to me what you say is true and then having us as groups looking at those posters and being like I’m not convinced. So, I think that the time was worth it. I don’t think that I would have done it that way if it weren’t for the Summer Academy experience.

Q: So you did PD for middle schoolers.

1- I think so too because we did museum walks for everyone of our and they had to give feedback on what they thought was good about it and was no longer, oh I liked your colors. They were really into the poster itself.

The group dynamic that we encountered in our PD almost sounds as if that something that you have kind of made your culture in your classroom. Is that accurate?

1- I think that is true, I think that I liked the way that it happened at the summer academy I thought that there were some really good conversations going on. There was a lot of really looking for detail. That is what I wanted to take back to my students. I want them to be very critical thinkers. And look at their work as well as others. And then know that we are going to do it again and again. We were probably going to be doing another poster or presentation of some kind. What do we really need for that. If we hadn’t done it multiple times I don’t think that would have been as effective. I think that by doing it a different way each time.

2- I would say that you can read about how to do stuff and then whether it is in your teacher book or in the professional development book. But you don’t really know what it feels like and your taking notes or your going to change something on the fly. So what the experience did for me was it was experience. And so yeah when I did it with my kids I constantly reflected back on how is was during the PD. I did model my experience very closely with the PD I received. I knew that I would be able to bring my summer experience into figuring out what was going well and what wasn’t going well.

Referring to Johnstone’s Triangle, has it affected your thinking about chemistry and your instruction?

2- When I did the slime posters, and the extension. I gave my kids the terms submicroscopic and macroscopic I put that in their guidelines. You need to be drawing pictures, and showing me paperclips if you want me to be able to visualize what you think those atoms are doing. I constantly said that those words aren’t enough what are you trying to say here and ok great you think this is happening on the submicroscopic scale how does this explain the goo. How does it explain the liquid left behind in the cup? So yes definitely, it gave me a new personal way to think about it. And it gave me the vocabulary to think about it. Yes I have kept that with me.

1- Even minus the terms I tried doing. I had done the chemistry without doing any of the analogies and then I went and did it with drama. Act out what the molecules are doing when its warm and solid liquid or gas. And then we transferred into what happens when we heat something up. They could not draw things; they couldn’t make any sense at all. But once we had done some of the posters, then they were able to do better. I got much more, realistic but also, I think that they truly understood it much better. By using some analogies or acting it out or having to draw it out. It was so much better.

2- I agree, we did the whole linking arms, in the hall way and try to fit through the door way and that is the mouth of the funnel. Suddenly kids were wanting to draw stick figures on their poster, this is us not walking through door and this is the slime not going through the funnel and this is
the paperclips and it helped.

1- I do think that the way you kept repeating made the difference because we did it in many different ways.  
1 – We stayed as a group the whole week, and that was important. I know that usually we change. I have done this as a presenter. Okay let’s change grouping. But we were able to take what we have done at one and grow with it. And discuss it, where you would have had to the next day start fresh get to know the person in the group. Who was going to do what, where by the end of the week we almost didn’t have to talk a lot. You know we were starting to mesh well.  
So you had comfort with the group, so did this make looking at the posters and making comments easier. If you are uncomfortable in the group, you are less likely to be uncomfortable twice by asking questions of the posters. Is that true?  
1- The comfort level but we had gone through the same experience.  

Q- One of the designs of the PD was the clickers. Which we ask content questions which for many people were intimidating. Because they said that they were going to be found out I don’t know this. That level of uncomfortableness is part of what allowed us to put you as students. You have to realize that we never really revealed who clicked on what, and in fact I haven’t looked at the data. The purpose was to introduce that concepts are hard. It opened the discussion of topics and people realized that they could get something out of the discussion. You had a whole group and a group group. I think those dynamics really help. When you think about when we partner kids, we want them to get comfortable the same way.  

1- I don’t remember I could do part of the balancing and Bob you remembered another part and we could mesh our understanding. So we could go on further with our knowledge.  
2- I remember that part two, so we each remember parts from our backgrounds that we could keep coming to answers that as a group we could feel good about.  

2- I just want to briefly comment that you pulled back the curtain a little bit. One of the things that we should keep in the next iteration is the tough questions. Getting us to feel like students. If you hadn’t challenged us we would have felt confident and cocky. It would have been a very different experience. I brought this feeling to the kids in my classroom. They are going to be lost. They are going to need to ask each other question. Getting us to feel like students was an integral part of the experience.  

Q- Your PD is going to be unsuccessful if your colleagues are unwilling to change. Because if they are stuck in the mud and they say well I’m not really going to change what I do. You’ve lost the battle already.  

1- I thought of all the PD we have done, the one that I took the most back from, and also just felt good about it every single day was the chemistry PD.
APPENDIX 11 THE PRESENCE OF 10 IDENTIFIED ELEMENTS (USING GROUNDED THEORY) IN PRE AND POST TEACHER SURVEYS

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<th>Element</th>
<th>Representation</th>
<th>Submicro level understanding</th>
<th>Limitation of Models</th>
<th>Model Revision</th>
<th>Hands on Engagement</th>
<th>Deeper Student Thinking</th>
<th>Communicate Science</th>
<th>Misconceptions</th>
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Clint Eaton was born in Troy, NY. He moved around the east coast frequently and graduated high school in Hereford, MD in 1995. In 1999, he received his Bachelor of Science in Chemistry, from East Carolina University in Greenville, NC. He has worked in numerous research oriented chemistry field including pharmaceutical, environmental, research and development, and tobacco. Currently he is teaching physical science at a local high school in Maine. He has been a co-author or acknowledged in three analytical publications. He is a candidate for the Master’s degree in Science of Teaching from The University of Maine in December, 2019.