Marquette University
e-Publications@Marquette

Distributed Scaffolding: Wiki Collaboration Among Latino High School Chemistry Students

Edwin Duncan O'Sullivan
Marquette University

DISTRIBUTED SCAFFOLDING: WIKI COLLABORATION AMONG
LATINO HIGH SCHOOL CHEMISTRY STUDENTS

by

Edwin Duncan O'Sullivan Jr., B.S., M.S.

A Dissertation submitted to the Faculty of the Graduate School,
Marquette University,
in Partial Fulfillment of the Requirements for
the Degree of Doctor of Philosophy

Milwaukee, Wisconsin

December 2013

ABSTRACT
DISTRIBUTED SCAFFOLDING: WIKI COLLABORATION AMONG
LATINO HIGH SCHOOL CHEMISTRY STUDENTS

Edwin Duncan O'Sullivan Jr.

Marquette University, 2013

The primary purpose of this study was to evaluate if wiki collaboration among Latino high school chemistry students can help reduce the science achievement gap between Latino and White students. The study was a quasi-experimental pre/post control group mixed-methods design. It used three intact sections of a high school chemistry course. The first research question asked if there is a difference in academic achievement between a treatment and control group on selected concepts from the topics of bonding, physical changes, and chemical changes, when Latino high school chemistry students collaborate on a quasi-natural wiki project. Overall results for all three activities (Bonding, Physical Changes, and Chemical Changes) indicated no significant difference between the wiki and control group. However, students performing the chemical changes activity did significantly better than their respective control group. Furthermore, there was a significant association, with large effect size, between group membership and ability to overcome the misconception that aqueous ionic reactants in precipitation reactions exist as molecular pairs of ions.

Qualitative analysis of classroom and computer lab dialogue, discussion board communication, student focus groups, teacher interviews, and wiki content attributes the better performance of the chemical changes wiki group to favorable differences in intersubjectivity and calibrated assistance, as well as learning about submicroscopic representations of precipitation reactions in multiple contexts. Furthermore, the nonsignificant result overall points to an aversion to peer editing as a possible cause. Drawing considerably on Vygotsky and Piaget, the results are discussed within the context of how distributed scaffolding facilitated medium levels of cognitive conflict.

The second research question asked what the characteristics of distributed metacognitive scaffolding are when Latino high school chemistry students collaborate on a quasi-natural wiki project. Results suggested a higher frequency of metacognitive scaffolding by the teacher, over peers, for content knowledge and making connections knowledge. Teacher metacognitive scaffolding often took the form of posting discussion board questions designed to stimulate student reflection on their content or creativity. On the other hand, both teacher and peer metacognitive scaffolding for general goals knowledge and strategy knowledge was relatively infrequent. Recommendations are offered for improving teacher and peer metacognitive scaffolding.

ACKNOWLEDGMENTS

Edwin Duncan O'Sullivan Jr.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1: Introduction

General Purpose

Adequate high school preparation is crucial if Latino and other minority students are to select and persist in Science, Technology, Engineering, and Math (STEM) majors (Cole & Espinoza, 2008). Not surprisingly, this assertion regarding the importance of secondary schooling has been applied to other disciplines (Nunn, 2011), but several indicators suggest STEM subjects deserve special attention due to very large achievement gaps. Compared to White students, of whom 72% were at or above basic level on the 2009 Grade 12 Science National Assessment of Educational Progress (NAEP), only 42% of Latinos were at or above the same benchmark (National Center for Education Statistics, 2012). At the state level, results are also poor. In Wisconsin, for example, on both the 2012 Grade 10 Mathematics and Science tests, the percentage of Latinos reaching advanced or proficient was considerably less than their White counterparts. In Math, 21.3% of Latinos reached this standard compared to 51.4% of Whites. The gap in Science was similar with 55.3% for Latinos and 82.9% for Whites (Wisconsin Information Network for Successful Schools, n.d.). These gaps also need to be considered in the context of overall poor results of U.S. students compared to their international peers (O. Lee, 2005).

The current study is explicitly focused on Latino students, and not necessarily English language learners (ELLs). However, many Latino students are ELLs. For example, 40% of Latino students in the state of Wisconsin were designated as Limited English Proficiency in 2012-2013 (Wisconsin Information Network for Successful

Schools, n.d.). Some evidence suggests that interventions can make a difference for ELLs, but the number of students receiving such specialized instruction amounts to about half of those who need it (Rumberger & Tran, 2009). Calls for action to reduce the achievement gap for linguistic minority students have come from as high as the federal level. For example, the No Child Left Behind legislation calls for:

> closing the achievement gap between high- and low-performing children, especially the achievement gaps between minority and non-minority students, and between disadvantaged children and their more advantaged peers. (Rumberger & Tran, 2009, p. 5)

One study that integrated science inquiry with the home cultures of diverse urban students found statistically significant gains for all groups for science knowledge and inquiry (O. Lee & Luykx, 2005). Further, some urban districts have successfully reduced achievement gaps to about half the national average (Rumberger & Tran, 2009). With that optimism to build off of, the general purpose of this study is to evaluate a wiki-based instructional intervention intended to help reduce the White-Latino achievement gap in science.

What is a wiki? In his history of wikis, Cummings (2008) offers a straightforward definition. Wikis are a "Web page that users modify" (2008, p. 5). The original wiki was created in 1995 and is attributed to software programmer Ward Cunningham. Today, by far the best known wiki is Wikipedia, founded by Jimmy Wales in 2003 (2008). Editing a wiki is often similar to using standard desktop publishing tools, such as Microsoft Word. For some wikis, the editing interface looks the same as what is displayed once the page is saved. For others it looks different. Access to pages can be limited and password protected, or open to the public. Wikis track every edit, including who contributed to the change. If a user wishes, they can review the wiki history and

revert to a prior version. Users can also opt to receive emails to inform them whenever an edit occurs (Matthew, Felvegi, & Callaway, 2009).

Studying exclusively Latino students has its advantages for two primary reasons. The first relates to the collaborative nature of the project. Minority students have been described as "relegated to near silence" in some class discussions (Nunn, 2011, p. 1236). These students feel compelled to conform to White, middle class modes of interaction and, as a result, don't feel comfortable. Similar findings have been described at the college level where Latino students, in spite of strongly disagreeing with classmates' comments, refrained from speaking up (Nunn, 2011). Second, focusing on Latinos to the exclusion of other groups takes us beyond typical studies where generalizations are made about the population at large. Such generalizations may not be applicable to particular subgroups. Rumberger and Tran (2009) assert that factors that increase student achievement overall don't necessarily reduce the achievement gap.   In Massachusetts, for example, both ELLs and non-ELLs achieve well above national norms. The achievement *gap*, however, is slightly wider than the national average.

Rationale

This section will spell out the rationale for a multi-faceted study in which a seemingly broad range of topics are covered, including Latino high school chemistry students, quantitative and qualitative analysis, online learning, distributed scaffolding, and metacognition.

Latino high school chemistry students. To my knowledge, research studies that focus on Latino high school chemistry students are rare (and possibly non-existent). An ERIC search for the subject headings "Secondary Education" and "Hispanic Americans"

(or "Hispanic American Students") and "Science Education" yielded only eight results. When the additional criteria of "peer reviewed" and "Reports – Research" were added, only one paper remained; it was unrelated to chemistry.

Quantitative and qualitative analysis. In her review of science education for English language learners, O. Lee (2005) concludes that qualitative studies far outnumber quantitative. Furthermore, the same can be said for science education more broadly. Searching the ERIC database for the subject headings "Science Education" and "Statistical Analysis" (or "Correlation" or "Effect Size" or "Meta Analysis" or "Regression (statistics)"), along with the further criteria of "Peer Reviewed" and "Reports - Research", produced 287 results. Whereas when everything but "Science Education", "Peer Reviewed", and "Reports - Research" was replaced with the more qualitative terms "Qualitative Research" (or "Case Studies" or "Ethnography" or "Focus Groups" or "Grounded Theory" or "Naturalistic Observation" or "Participant Observation"), 436 hits resulted, an increase of almost 150.

Two clarifications are necessary. The first is that the current study is explicitly about Latino students, and not necessarily English language learners, as was stated earlier. However, the student body at the participating school is over 95% Latino, and 22.3% of those are classified as limited English proficiency. Furthermore, the percentage of students scoring at the Grade 10 Advanced or Proficient level in Reading was considerably less than the statewide mark (11.7% vs. 38.45% respectively) (Wisconsin Information Network for Successful Schools, n.d.). The point is, a gap in the literature regarding ELLs, such as that reported in O. Lee (2005), speaks to a research gap applicable to the demographics of the participating school in the current study. Second,

while quantitative analysis will help fill a research gap, qualitative will also be performed because interpretive methods are needed to inform the answer to the first research question and to answer the second research question about the specific characteristics of distributed metacognitive scaffolding. As Gnadinger (2001) suggests, "Qualitative researchers are concerned with the process not simply with the outcomes and products" (p. 68).

      Online learning. Cuban criticized computer usage in K-12 schools as doing nothing more than "maintain[ing] rather than alter[ing] existing classrooms practices" (Cuban, 2001, p. 71). A review of his book, however, suggests that he "gives too little weight to the slow-revolution explanation" for educational change (Schweizer, Hayslett, & Lowe, 2003, p. 281). It seems worthwhile, then, to evaluate computer usage in schools a decade later. For online learning in particular, more studies have been done at the college level than K-12 (Richards, 2012). Again, an ERIC search supports this. Searching for "Distance Education" or "Blended Learning" or "Online Courses" or "Virtual Classrooms" or "Web Based Education", and then limiting that to "Reports – Research", "Peer Reviewed", and "Postsecondary Education" gave 67 hits. Doing the same search, but this time limiting to "Secondary Education" instead of "Postsecondary Education" produced only 45 hits. Some K-12 research has suggested that computer based learning is effective, in particular as it applies to using computer scaffolds that facilitate collaboration (Butler & Lumpe, 2008). Thus, the current study, itself featuring collaborative learning, is needed to evaluate a mechanism by which computers might be used transformatively, rather than as Cuban asserted they are, simply to maintain existing practices.

Distributed scaffolding. Distributed scaffolding is described by Tabak (2004) as incorporating "multiple forms of support that are provided through different means to address the complex and diverse learning needs" in today's multifaceted educational settings (p. 305). Studies therefore should evaluate the degree to which teacher, peer, and computer-based scaffolds work in concert (Wu, 2010). Unfortunately, such studies are uncommon. In her review of technology-enhanced scaffolding in science, Wu (2010) found that only four of 56 studies incorporated the complementary use of teacher, peer, and computer supports[1]. This is problematic for two reasons. One is that without the *combined* efforts of a more knowledgeable other and the computer-embedded scaffold, it is not possible to adequately assess if students have understood the information provided by the computer support. Second, students might simply ignore the computer support in the first place (Wu, 2010). As Wu (2010) concludes, "With the lack of teacher support, scaffolding applications cannot be as effective in technology-enhanced learning contexts" (p. 27).

Metacognition. Distributed *metacognitive* scaffolding will be the focus of the second research question. Collins, Brown, and Newman (1989) describe that it is possible to develop in students the same critical "self-correction and monitoring skills" so commonly found among disciplinary experts (p. 458). The key is to have extended dialogue between expert and learner as they jointly problem solve. Falling under the umbrella of cognitive apprenticeship, they elaborate that learning effective metacognition

---

[1] It is important to note that what Wu (2010) meant by *computer supports* was generally a prompt incorporated into an interactive program. For example, if a student answers a question within the program one way, they are provided, by design, one particular prompt. If they answer another way, they receive another prompt. This differs from the computer supports in the current study. In this study, computer supports or computer-based scaffolding will be taken to mean any form of computer support the learner has access to that does not rely on dynamic interaction with the teacher or a peer. Examples include searching Google or using a Help link embedded in the wiki. In either of those instances, an individual can receive support without necessarily needing the assistance of a teacher or peer.

involves "development and externalization of a producer-critic dialogue that students can gradually internalize. This [is] accomplished through discussion, alternation of teacher and learner roles, and group problem solving" (Collins et al., 1989, p. 458).

Although the current study does not involve teacher-student joint problem solving per se, it does incorporate the spirit of that interaction. That is, the study will evaluate ways in which (1) the teacher, in the role of content expert, and (2) the peer, in the role of collaborator, make transparent how they monitor current understandings, and adapt accordingly. Studies looking at how teachers scaffold metacognitive thinking are not uncommon (Davis, 2003; Eslinger, White, Frederiksen, & Brobst, 2008; Kurt, 2007; Manlove, Lazonder, & Jong, 2007). On the other hand, Choi, Land, and Turgeon (2005) found that peers had difficulty in generating questions which effectively promoted metacognition among their fellow students, even with instructor support. They conclude that future studies should assess peer-generated questions and their ability to facilitate reflective thinking in others. The current study does its part to address that need.

Research Questions

Two research questions frame this study. They are:

Research Question 1: Is there a difference in academic achievement between a treatment and control group on selected concepts from the topics of bonding, physical changes, and chemical changes, when Latino high school chemistry students collaborate on a quasi-natural wiki project?

Hypothesis 1: As measured by posttest scores, the academic achievement of the treatment group will be greater than that of the control group.

Research Question 2: What are the characteristics of distributed metacognitive

scaffolding when Latino high school chemistry students

collaborate on a quasi-natural wiki project?

Hypothesis 2: The teacher will be more effective than peers at facilitating

metacognitive thinking in learners.

The first hypothesis is based on the notion that the distributed scaffolding inherent in a

wiki activity offers students the best opportunity to learn an often abstract subject like

chemistry. The second hypothesis is based on an overall evaluation of scaffolding

literature and the favorable, albeit qualified, nod it gives to teachers over peers in terms

of quality of support. As just one example, teachers are generally stronger in content, and

peers often more interested in completion than learning (Rogoff, 1990). The rationale for

these hypotheses will receive much greater coverage in the Review of the Literature

chapter, to which I now turn.

Chapter 2: Review of the Literature

The first and largest section of this literature review will be devoted to three theoretical frameworks. The first is *cognitive conflict*. By drawing considerably from the work of Vygotsky, Piaget, and others, I will demonstrate two fundamental characteristics of learning and development: cognitive conflict is essential, and conflict at a medium level is ideal. The second is *scaffolding*. General characteristics will be discussed initially, followed by more nuanced interpretations of *metacognitive scaffolding* and *distributed scaffolding*. The third theoretical framework is *cultural congruence*. The focus here is culturally relevant instruction for Latino high school students.

It has been suggested that understanding science learning requires pooling multiple theoretical perspectives, rather than focusing on just one (O. Lee & Luykx, 2005). This study embraces that viewpoint. In support of this, Driscoll (2005) writes "many theories may each provide insight into some aspect of learning and development…what one theory conceals, another illuminates" (p. 261). As was said more succinctly by Bornstein and Bruner (1989), "The age of global claims appears to be at an end" (p. 13). Tying together the multiple theories, I will illuminate the central, binding assertion of this study. That is, distributed scaffolding (metacognitive or otherwise) is better suited to promote medium cognitive conflict than teacher-student, peer-student, or computer-student scenarios can do alone.

The second main section of this chapter will review studies focused on science education, with an emphasis on quasi-experimental studies in adolescent chemistry classrooms. The third and final section will deal with research on wikis in educational settings. Both of these review topics were needed to inform the experimental design of

the current study.

Theoretical Framework

 Cognitive conflict. What is meant by the expression *cognitive conflict*? The

terms *cognitive conflict*, *cognitive dissonance*, and *incongruity* (or *incongruence*) will be

taken to refer to the same concept throughout this paper[2]. Cognitive conflict will be the

default term. (To avoid misrepresenting original author's intended nuanced meanings,

however, the other terms will be used when directly referencing their work.) Cognitive

conflict can be generated in various ways, such as a surprise result that runs counter to

one's expectations, a simple intellectual curiosity, or disequilibria which results when an

individual recognizes cognitive gaps as they try to apply their existing schemas to new

situations (Niaz, 1995).

 Some details from a recent investigation involving wikis will help elucidate

further the meaning of cognitive conflict. The researchers had college students read

several pamphlets on the various causes of schizophrenia, a topic they presumably had

little prior knowledge of (Moskaliuk, Kimmerle, & Cress, 2009). The researchers further

presumed that after reading the pamphlets, all students would now possess the same

degree of knowledge of the topic. The guise of the experiment was that students were

told they were about to use what they learned from the pamphlets and contribute to the

---

[2] See Chapter 1 in Festinger (1957) for an introductory discussion of cognitive dissonance. He suggests "two elements are in a dissonant relation if, considering these two alone, the obverse of one element would follow from the other" (1957, p. 13). He gives several examples of dissonant cognitions, such as a man standing in the rain who fully expects himself to get wet, yet sees no evidence of himself getting wet (1957, p. 14). He also offers that the terms "hunger", "frustration", or "disequilibrium" could easily substitute for "dissonance" (1957, p. 3). See pages 24, 25 and 287 of Berlyne (1960) for a discussion of incongruity. He describes incongruity as occurring "when a stimulus induces an expectation, which turns out to be disappointed by the accompanying stimuli….Incongruity requires not merely a combination of stimuli that is novel but a combination differing from, yet having components in common with, one that the organism has learned to treat as more likely" (1960, p. 24-25).

development of a real clinical psychology wiki. It supposedly would be read by real patients, their families, and others.

Before students began building their wikis, the researchers populated the pages with content such that three conditions existed. Some wikis had content from all the pamphlets. This was described as low incongruence (i.e. low cognitive conflict) because it was presumed students would understand just about all the preexisting content. Other wikis, however, had content preloaded such that only half the pamphlets were represented. This was described as medium incongruence. Finally, some students began their wikis with blank pages. This scenario was high incongruence as a considerable gap existed between the students' knowledge of the topic and the lack of it represented on the pages. That is, all the students had a fair amount of knowledge after reading the pamphlets and there was *no* knowledge represented on the wiki page. Another presumption in this study was that the degree of conflict was related to content knowledge gaps rather than those of task demands. The research question dealt with which condition best supports learning. The answer to that question will be discussed later in this paper.

When students engage in learning activities, formal or otherwise, they may at times have "overly personal and individualistic interpretations" of the content (De Lisi, 2002, p. 7). Critical aspects of a particular problem are "either ignored or misinterpreted in favor of the child's current level of understanding" (2002, p. 7). This would be a low cognitive conflict scenario. At first glance, this description may seem at odds with what was described above in the wiki low cognitive conflict example. In that case, students who had the content from all the pamphlets presumably understood it all and hence their

knowledge level of schizophrenia was closely aligned with the preexisting wiki content.

Both are low cognitive conflict, however, because this results not only from

understanding all the content, but also if one *perceives* they understand all the content. In

either case, critical features of the problem are glossed over by the student who *thinks*

they know it all. For example, low cognitive conflict could develop as follows. A

student is assigned the task of reading sources for a research report. They end up

choosing textual material far above their own ability. In this case, the student might end

up misrepresenting the author's intent because they believe, mistakenly, they understand

it well and they may "fabricate ideas in a report in such a way that the author's intention

is not represented at all" (2002, p. 9).

Another student, seeking sources for the same research report, might also select

challenging material. Although low cognitive conflict *could* develop, as described above,

it is also possible that high cognitive conflict could result. The student may recognize,

correctly so, that they understand little from the reading. They may then copy text

verbatim without any accompanying comprehension (De Lisi, 2002). This too is not

inconsistent with the high cognitive conflict described above in the wiki study. In that

case, students who began with blank wiki pages had a large gap between their knowledge

(from having read the multiple pamphlets and presumably understanding them) and the

content (or lack of it) preloaded on the wiki. The student who chooses text far above

their reading level, and who realizes it, also has a large gap between their knowledge

level and that in the reading source.

Thus, we have seen that cognitive conflict occurs when a learner recognizes or

perceives inconsistencies between their current understandings and new information.

Further, these conflicts (i.e. dissonances, incongruences) can exist to various degrees. This raises several questions, especially as it pertains to adolescents learning chemistry. If cognitive conflict is a prerequisite for learning, how does the degree of conflict (low, medium, or high) impact the quality of learning? What learning environments and scenarios best promote ideal levels of cognitive conflict? How does cognitive conflict interact with the developmental level of adolescents, in particular when it comes to learning abstract concepts? Two theorists who have addressed such questions (although not necessarily explicitly as they pertain to chemistry) are Vygotsky and Piaget.

   Vygotsky and Piaget. Emphasis is often placed on how Vygotsky and Piaget differed in their respective theories of development and learning. For example, Piaget is often associated with the individual and Vygotsky the social (Marusic & Slisko, 2012). This perceived divergence has led some Vygotskyians toward didactic teaching (between a more knowledgeable other and a learner) and Piaget supporters to more open educational settings (DeVries, 2000). In their introduction to *The Vygotsky Reader*, van der Veer and Valsiner (1994) suggest that in the 1970s, the Vygotskian perspective gained favor as "Piaget-ascribed individual learning freedom of pupils was threatening the authority and control functions of teachers" (p. 4). Regardless where the pendulum stands today, areas of agreement between the two men have probably been overshadowed because of "partial" and "one-sided" borrowing from their ideas (1994, p. 4-6).

   For example, both theorists converged on at least three aspects of learning and development. First, both believed that both social *and* individual factors play a vital role in development. Although most of his research was in laboratory settings with individuals, DeVries (2000) quotes Piaget as writing "social life transforms the very

nature of the individual" and development is "due to social mechanisms" (p. 190). As for Vygotsky, "the focus on the individual developing person which Vygotsky clearly had…has been persistently overlooked" (L. S. Vygotsky et al., 1994, p. 6; as part of the introduction by van der Veer & Valsiner). Second, even though Piaget's stages of development (sensorimotor, preoperational, concrete operational, formal operational) are much more commonly cited (Driscoll, 2005, p. 195-198; Piaget, 2008, p. 19; and many others), Vygotsky also had a stage theory he intended to publish shortly before he died (van der Veer, 1986). For both Piaget and Vygotsky, each stage represented a "qualitatively" different mental structure (Driscoll, 2005, p. 194; van der Veer, 1986, p. 528). Third, and perhaps most important for the present study, is that both men felt that cognitive conflict leads to cognitive growth (Niaz, 1995).

With that as our backdrop, I will now more fully address these issues by focusing on each theorist individually, starting with Vygotsky. In the end, however, we will see that whatever their similarities and differences, they not only agreed that cognitive conflict is necessary for learning and development, but that it is ideal when occurring at the medium level.

Vygotsky. Vygotsky's emphasis was social institutions and activities, and their impact on learning (Rogoff, 1990). He offered that it is from collaborative problem solving that human cognitive growth occurs (Marusic & Slisko, 2012). He asserted that it is collaboration, accompanied by the inevitable disagreements, which produce cognitive conflict. It is this conflict that speeds up cognitive development as individuals seek a settlement with those they disagree with (2012). It is important to note, however, that although "countless investigators of mother-child dialogues and joint problem

solving" feel compelled to invoke Vygotsky, the Russian psychologist "never discussed these situations" (L. S. Vygotsky et al., 1994, p. 6; in the introduction by van der Veer & Valsiner). Rather, he stressed how the culture *at large* supports the development of an individual. Only by social interactions with "people in his environment and in cooperation with peers" is learning able to stimulate development (L. Vygotsky, 2008, p. 35). The way in which social interactions modify mental structures, however, is not direct, according to Vygotsky. Rather, the process is mediated by *signs* and *tools* (Driscoll, 2005).

　　　Mediation with tools and signs. In its most generic sense, a *sign* is something that represents something else, often for the purpose of making sense of something or for problem solving. For example, an algebra student might let "x" stand for a particular variable in order to solve a math problem (Driscoll, 2005). Vygotsky considered there to be three types of signs. First, *indexical* signs deal with cause and effect, such as smoke (effect) being a sign of fire (cause). Second, *iconic* signs are symbols such as a trash can on a computer screen representing the depository for deleting files. For our purposes, the third type of sign is most relevant. These are *symbolic* signs that are abstract representations of what they stand for. An example of this, from a Vygotskian perspective, would be language, where words are the symbolic signs that represent objects (Driscoll, 2005). For the current study, we will extend "language" to also mean the "language of chemistry". The abstract signs used in chemical nomenclature are numerous. A sodium atom might be represented by the word "sodium", by the symbol "Na", by a circular representation on a computer screen or piece of paper, or a spherical ball a student might hold in their hand, among others. Each of these is a symbolic, highly

simplified sign that chemists use to represent very complex sub-microscopic particles, all for the purpose of sense making.

For Vygotsky, language is the most important sign system because "It provides for decontextualization, wherein signs (or words, in this case) become more and more removed from a concrete context" (Driscoll, 2005, p. 259). Driscoll (2005) provides the clarifying example of a child who encounters a horse for the first time and thus associates the word "horse" with a specific animal, not a species. As development progresses, however, the child is able to generalize the concept such that it applies to situations involving any horse. Vygotsky would go as far to say that the sign system of language, and the social interactions in which it is utilized, are essential for cognitive growth. That is, he believed that thought and language were distinct; language being the higher mental function.

For example, an animal that senses fire might immediately have a mental image of it and associate that with danger. On the other hand, a human who sees the same fire can immediately employ verbal thought, centered on an abstract form of the word "fire", and assess whether or not there is immediate danger, delayed danger, how to react in either case, whom to contact, and so on. It is the abstractness of the word "fire" (the word itself looking *nothing* like how actual fire looks), as a symbolic sign, that enables the various options. The human readily associates the word "fire" with other words from the language, much more seamlessly than an animal, or human, can associate an image with other images. According to Vygtosky, even animals possess lower mental functions such as nonverbal thought (Gnadinger, 2001). The major point to emphasize here is that development of higher order thinking corresponds to the ever-increasing abstractness of

symbolic signs. Further, Driscoll (2005) notes that *any* symbol system will facilitate

abstraction, it doesn't have to be traditional languages (italics added). Thus, here again

we see support for applying Vygotsky's theories to the language of chemistry.

A study Vygotsky carried out with different peoples of Soviet Central Asia further

emphasizes the importance of language and words as a sign system (Driscoll, 2005). The

subgroups of the population differed in their literacy levels. The results of the study were

that the less literate society grouped items from the study by context in a concrete setting

(hammer, saw, hatchet, log), whereas the more literate group itemized based on

decontextualized function (hammer, saw, hatchet only) (2005, p. 250). From this,

Vygotsky concluded that the "the [more] literate society represented a later point in social

evolution than the nonliterate society, and therefore, should have evolved higher

psychological functions" (2005, p. 249). By "higher psychological functions", Vygotsky

was saying the more literate society generally employed more abstracted word meanings.

In his own words (translated from Russian), this time comparing children to adults, rather

than two societies:

> A child and an adult who understand one another when they utter the word "dog",
> relate this word to the same object, having in mind the same real context, but at
> the same time one of them is thinking of the concrete complex[3] of dogs, whilst the
> other's thought is the abstract concept about a dog. (L. S. Vygotsky et al., 1994, p.
> 244)

Perhaps more importantly, for psychological development, Vygotsky stressed not only

audible utterances, but also the inner speech one engages in when thinking. Thus, when

the child speaks and thinks about a "dog", he does so in a manner that does not "coincide

with the operations carried out in the thinking of an adult when he pronounces one and

---

[3] We will discuss the term *complex* in more detail later. For now, it is enough to consider it to mean a less
abstracted understanding of a word.

the same word" (1994, p. 243).

In addition to signs, mediation between external social activities and internal mental functions can be accomplished with *tools*. A tool is "something that can be used in the service of something else" (Driscoll, 2005, p. 251). Again, Driscoll (2005) provides an illuminating example, one of a chimp who desires to reach a banana and ends up using a stick as a "banana-reaching" tool (2005, p. 251). To fully understand Vygotsky, one must consider the cultural environment in which he lived. In early 20th century Russia, Marxian ideology was gaining favor. Vygotsky was one who embraced Marx's idea that "socially organized labor activity, which is founded on the use of technical tools, is the basic condition of human existence" (Driscoll, 2005, p. 249). These same tools thus impact not only how people act, but also how they think. Development is directly related to the "internalization of the tools of one's culture" (2005, p. 249).

Vygotsky, however, extended the meaning of a "tool" to mean more than just material objects, such as a hammer or pencil. Unlike material tools that give us "some control over nature", he suggested we use *psychological tools* to "give us control over our mental behavior" (Gnadinger, 2001, p. 28). Returning to the algebra example, I've already noted that "x" can be considered a symbolic sign because it stands for some variable. A tool, on the other hand, might be the technique of using cross-multiplication to solve the problem, such that one isolates and solves for "x". As another example, in chemistry the symbol "Na" serves as a symbolic sign for a sodium atom, as stated above. When this sign is grouped in a periodic fashion with other elements to form the periodic table, the table itself can be thought of as a tool. "One of the principal roles of the

periodic table is as a teaching *tool*, given that it unifies so much chemical information and establishes unity amidst the diversity of chemical phenomena" (Scerri, 2007, p. *xx*; italics added). Vygotsky would likely assert that higher mental processes develop when sign and tool usage in algebra and chemistry become internalized (Driscoll, 2005). Thus, the more that cross multiplication and the periodic table become an internal and abstract psychological tool, the greater our intellectual development.

In our attempt to understand Vygotsky, and how his theories apply to the current study, I so far have introduced the importance of signs and tools, and how they are mediators between social interactions and mental structures. In doing so, we have begun to see the critical role that language plays. I've shown how the language of chemistry seamlessly fits into what Vygotsky would classify as a symbolic sign system. I have yet, however, begun to directly address how Vygotsky felt about some of the fundamental characteristics of learning and development stated at the outset of the literature review. That is, cognitive conflict is essential, conflict at a medium level is ideal, and it is best promoted by distributed scaffolding. In other words, we need to begin to answer the question, what learning environments and scenarios best promote medium levels of cognitive conflict? Thus, I will now turn to Vygotsky's notions that related to instructional scenarios, introducing his best-known formulation, the *zone of proximal development*.

Zone of proximal development. It is indeed "conflict-generating dilemmas", Vygotsky thought, that promote learning (Driscoll, 2005, p. 257). Further, as has been suggested above, he believed it is the "medium-level questions" that are ideal (2005, p. 256). Instruction that generates conflict too low or too high will be less effective. Low

cognitive conflict will not push the learner to adapt mental structures. Too much

cognitive conflict is equally problematic; leaving the learner no point of reference to

build off of. As Vygotsky himself put it:

> It is well established that the child can imitate[4] only what lies within the zone of his intellectual potential. If I am not able to play chess, I will not be able to play a match even if a chess master shows me how. If I know arithmetic, but run into difficulty with the solution of a complex problem, a demonstration will immediately lead to my own resolution of the problem. On the other hand, if I do not know higher mathematics, a demonstration of the resolution of a differential equation will not move my own thought in that direction by a single step. To imitate, there must be some possibility of moving from what I can do to what I cannot. (L. S. Vygotsky, Rieber, & Carton, 1987, p. 209)

For Vygotsky then, one could say there is cognitive conflict, and then there is cognitive

conflict *that has an impact*. As Rogoff described it, referring to Vygotsky's zone of

proximal development (ZPD), "child development proceeds through children's

participation in activities *slightly* beyond their competence" (Rogoff, 1990, p. 14; italics

added). "Slightly beyond their competence" is, in so many words, "medium cognitive

conflict".

An individual's ZPD has been defined as "the difference between the level of

solved tasks that can be performed with adult guidance and help, and the level of

independently solved tasks" (Marusic & Slisko, 2012, p. 306). The presumption here is

that effective instruction will promote cognitive development to a level not possible

without it (at least not on the same timetable). The ZPD has been said to extend up to 2

years in mental age beyond the current ability level (Marusic & Slisko, 2012). A too

ambitious mentor, whether it is teacher, parent, or peer, will ask too much of the learner,

creating learning conditions far beyond their ZPD. This could be asking a student to

---

[4] For Vygotsky, the word "imitate" did not mean to simply copy the action of another. Rather, it assumes a considerable degree of understanding of the problem being solved (Chaiklin, 2003).

solve problems that are "over their head", akin to high cognitive conflict. To draw upon the example earlier of the student seeking reading sources for a research report, instruction well beyond the ZPD would likely result in the student understanding little, and perhaps resorting simply to memorizing content with limited chance of cognitive restructuring. In a high school chemistry class, an extreme example of this might be a teacher beginning an introduction to atomic structure by discussing the fundamentals of quantum mechanics.

On the other end of the spectrum, significant learning is also unlikely if students are instructed near the bottom of, or even below, their ZPD. In this case, there is simply not enough cognitive conflict to promote learning or development. This can transpire in a number of ways. One is simply to provide instruction that is repetitive to an excess. Another is to provide diluted content, to the point of not at all challenging the learner. For example, a young child learning English sight words might encounter this when trying to understand the letter combination "ee", as in "teen", generally makes the long "e" sound. The child could possibly experience low cognitive conflict, after having mastered the general concept for words such as "seen", "jeep", "cheep" and so on, if the teacher or parent never introduced anomalies such as "been". Low cognitive conflict could also result, as we saw earlier, from a learner's *perception* of understanding, such as the student who perceived they understood the research material well, when in fact they did not.

It can be said then, that the ideal level of assistance occurs when learners are asked to perform at the upper limit of their ZPD, corresponding to medium cognitive conflict. However, a crucial factor in the way this is operationalized has yet to be

mentioned. Teaching in the ZPD means the social interaction between the more

knowledgeable other, and the learner, must involve *intersubjectivity* (Driscoll, 2005).

That is, although the Vygotskian perspective posits an inequality between partners, this

pertains only to the degree of knowledge about the relevant content or skill. The

remaining aspects of the learning scenario are wholly equal and collaborative.

Intersubjectivity requires both teacher and learner to "co-construct the solution to a

problem or share joint decision making about the activities to be coordinated in solving

the problem" (2005, p. 258). Reciprocal teaching is cited as an example. Students, with

the teacher's assistance, collaboratively try to understand a reading passage. Initially the

teacher leads the discussion, but gradually more and more responsibility is passed along

to the students, who eventually take turns making decisions on how to lead the sense-

making activity. Some studies have shown intersubjectivity is central if "advances in

development" are to occur (2005, p. 259), and it is to the ZPDs emphasis on *development*,

as opposed to *learning*, that I will now turn.

Chaiklin (2003) asserts that the use of the term *development* in *zone of proximal*

development is not coincidental. Otherwise, he asks rhetorically, "why not name it the

'zone of proximal learning?'" (2003, p. 42). Vygotsky clearly puts the emphasis on

development, as opposed to simply learning:

> The zone of proximal development defines those functions that have not yet
> matured but are in the process of maturation, functions that will mature tomorrow
> but are currently in an embryonic state. These functions could be termed the
> "buds" or "flowers" of development rather than the "fruits" of development. The
> actual developmental level characterizes mental development retrospectively,
> while the zone of proximal development characterizes mental development
> prospectively. (L. Vygotsky, 2008, p. 33)

Just as a "bud" or a "flower" is a precursor of a "fruit", so much so that they are

qualitatively and unmistakably a more immature form, so Vygotsky meant that

instruction in the ZPD can take us from a less developed mental structure to a more

advanced, qualitatively different one. In fact, the nature of the social interactions in the

ZPD are so critical, that if they are poor, they can lead to "developmental delays or

abnormal development" (Driscoll, 2005, p. 257). If done right, however, it could lead to

"normal or accelerated" development (2005, p. 257). It was Vygotsky's intention,

consequently, to differentiate between ordinary instruction and instruction geared toward

developmental growth. The point here is that the "zone of proximal development is not

concerned with the development of a skill of any particular task, but *must* be related to

development" (Chaiklin, 2003, p. 43; italics added).

Scholars have lamented the fact that this has not always been the case. Palincsar

(1998) suggests that although the "negotiated nature" of some learning scenarios is

indeed supported by reference to the ZPD, nevertheless "it is perhaps the most used and

least understood constructs to appear in contemporary educational literature" (1998, p.

370). Research on scaffolding, joint problem solving, and other related activities, while

certainly meaningful according to Chaiklin (2003), have frequently invoked the ZPD

without a reference to developmental theory, explicit or otherwise. He posits, "there is

no additional scientific value to refer to [most investigations] as zone of proximal

development unless one concurrently has a developmental theory" to support them (p.

59). Rather than this being a benign shortcoming, indiscriminate use of the ZPD raises

the risk of the term "becoming so amorphous that it loses all explanatory power"

(Wertsch, 1984, p. 7). Thus, if the ZPD is to be used for explanation rather than merely

description, it is essential to relate it to maturing cognitive functions. For this reason, I

will now backtrack a bit and discuss Vygotsky's theory of development in general. I will make a case that it *is* appropriate to link the zone of proximal development with a collaborative high school chemistry project, wiki based or otherwise. As we will see, Vygotsky might suggest that for an adolescent to come to understand chemistry concepts, it requires more than learning. It requires development.

Vygotsky on development. Gnadinger (2001) has described the four main characteristics of development according to Vygotsky. Three of the principles explicitly reflect the design of the current study. The fourth also does, by implication, but more importantly it will provide us with an accessible pathway for linking development to adolescents learning high school chemistry. First, Vygotsky suggested that *children construct knowledge* (2001, p. 27; italics in original). That is, in line with other constructivists, he did not believe that learners were blank slates just taking in the "real" knowledge that is outside them (Driscoll, 2005; my own quotes). To the contrary, "learners form, elaborate, and test candidate mental structures until a satisfactory one emerges" (2005, p. 387). Social interactions are said to facilitate this (Gnadinger, 2001). Hence, it is straightforward to view a collaborative wiki project, as potentially contributing to development. Second, and relatedly, Vygotsky believed that *development cannot be separated from its social context* (2001, p. 27; italics in original). Therefore, an analysis of development must consider an individual's cultural and social milieu.

A third principle, according to Gnadinger's (2001) description of the Vygotskian perspective, is that *language plays a central role in development* (p. 28; italics in original). We have already seen that Vygotsky felt language is the most important sign, because it allows for a high degree of abstraction. This decontextualization of the words

of a language is facilitated by dialogue. Only through conversation, Vygotsky would say, can the shortcomings in an individual's thought processes, their misconstrued understandings, become "explicit and accessible to correction" (2001, p. 28). Further, the use of language provides a mechanism for exposure to alternative viewpoints (2001). In the case of a wiki activity, in particular one that incorporates various communication modes, both written (such as in the wiki discussion forum) and verbal (such as face-to-face computer lab meetings), communication allows individuals to use words to elaborate their ideas for the benefit of others, and themselves.

A fourth principle of development, as understood by Vygotsky, is that *learning can lead development* (Gnadinger, 2001, p. 27; italics in original). This is often put forth as a stark contrast to Piaget. That is, Piaget is frequently cited as believing that development leads learning (Gnadinger, 2001). As I've already described above, this viewpoint has some elements of misrepresentation. Piaget thought both social and individual factors contribute to development. Nevertheless, Vygotsky was a much greater advocate for a developmental theory that not only incorporated social interactions, and the concomitant learning it brings, but one that *emphasized* them. Thus, if learning does indeed lead development, and instruction in the ZPD is intended to promote cognitive development, I need to establish that learning chemistry, as a teenager, requires *development*. That is, that it requires qualitative changes to mental structures. For this argument, I will rely on a description of Vygotsky's stages of development, culminating with an emphasis on his last, most mature stage. It is here, Vygotsky believed, that for the first time, an individual learns to reason in *concepts*.

Stages of development. Although his stage theory is less well-known than

Piaget's, both men believed, as noted above, that an individual's cognitive growth is characterized by "qualitatively" different stages (Driscoll, 2005, p. 194; van der Veer, 1986, p. 528). That is, by the time someone reaches adulthood, their schemas are not merely expanded forms of childhood cognitive frameworks; growth is not simply a function of assimilating ever more knowledge onto the same foundational structure. Rather, moving from infancy to adulthood, one transitions through stages, each characterized by a different, ever more advanced cognitive structure. Vygotsky suggested there were five mental stages: infancy (0.2 – 1 year), early childhood (1 – 3 years), preschool age (3 – 7 years), school-age (7 – 13 years), and adolescence (13 – 17 years) (van der Veer, 1986, p. 530). At first glance, the last four appear to correspond fairly closely, at least in age ranges, to Piaget's stages.

According to Vygotsky's theory, each stage consists of long stable periods, of roughly one to four years, followed by a sudden transformation brought on by crisis (Chaiklin, 2003; Mahn, 2003; van der Veer, 1986). Regarding the relatively short, transformative periods, Vygotsky felt "the changes in individual processes and social relations during critical periods are so profound that they often to lead to crises for the child" (Mahn, 2003, p. 122). The implication here is that considerable cognitive growth can occur during these critical periods, if one achieves successful resolution of the crisis. However, another distinction with Piaget is worth noting at this point. Unlike Piaget, Vygotsky felt that crisis left unresolved, or one that was poorly resolved, could lead to "standstill and even regression" (van der Veer, 1986, 528). Piaget, on the other hand, felt that regression to a previous stage never occurs (Driscoll, 2005).

All this is not to say that qualitative cognitive changes do not occur during the

long stable phases. The difference here is that growth is more gradual, there is "slower, more incremental" development during these extended periods (Mahn, 2003, p. 121). To my knowledge, how one might identify whether or not an adolescent chemistry student might be experiencing a shorter, crisis period, or a longer, stable period, was not directly addressed by Vygotsky. Nevertheless, Vygotsky felt that transition to a new stage requires the development of what he called a "new formation" (van der Veer, 1986, p. 530). This new formation represents a higher form of mental activity, not merely a quantitatively enhanced version of what came before. It follows then, that one can make progress towards this new formation regardless if they are experiencing a long, stable period, or a shorter, critical one. The difference is only in rate.

What is this new formation, then, that characterizes transition to Vygotsky's fifth and final, and most mature stage? This is the adolescent stage that is defined as roughly corresponding to the 13 – 17 year age group. Quoting Vygotsky, Mahn (2003) writes the adolescent "masters for the first time the process of concepts, that he makes the transition to a new and higher form of intellectual activity – to thinking in concepts" (p. 132). I will now describe in more detail Vykotsky's thoughts on this adolescent stage, with an emphasis on how concepts develop. We will see that by forming concepts, the adolescent is now able to organize reality in manner that allows for understanding "systems of interconnections" (2003, p. 133). Understanding the "systems of interconnections" in chemistry, such as why all halogens generally have similar chemical reactivity, or why all acids generally react with bases, or why all nucleophiles generally attack a carbonyl carbon, lies at the heart of making sense of a complex, molecular level world.

Concept formation in adolescence. Vygotsky expressed dismay about how some

of his contemporaries viewed development. In particular, he disagreed that all that occurs in adolescence is merely an "amplification" of existing structures (L. S. Vygotsky et al., 1994, p. 190). He criticized those who believed that "puberty does not really mark the appearance of any sort of new intellectual operation in the thinking sphere which cannot already be found in a three-year-old child" (1994, p. 186). To the contrary, he believed that adolescence "is not just an exceptionally more complex lower form [of mental activity] quantitatively… but it represents a new, basically different type" (1994, p. 214). This qualitatively different mental activity is the ability to reason with concepts. I will now briefly describe Vygotsky's theory of how concepts form (itself being a stage theory), and in doing so, once again come back to his emphasis on signs, which he describes as a "basic and indispensable part" of concept formation (1994, p. 212).

Vygotsky suggested there were three stages of concept formation (as a point of clarity to the reader, this refers directly to Vygotsky's three stages of *concept* development, not his five stages of general cognitive development mentioned several paragraphs back, although both are certainly associated). Progressing through the stages essentially amounts to an ever-increasing ability to apply signs in an abstract manner. The first stage is described as a "syncretism of childhood perceptions" (L. S. Vygotsky et al., 1994, p. 216). That is, a young child, in an undefined way, will assemble separate objects in groups based on perceived similarities. In other words, the objects are "superficially connected, but intrinsically disconnected" (1994, p. 216). Vygotsky does not offer a specific example. Had he, he might have mentioned a child who makes a statement completely incomprehensible to an adult, and then gets frustrated because the adult, who thinks in fully formed concepts, does not understand what is apparently very

clear to the child. At this stage, the child may be thinking more so in images, rather than words, and not able to reach the degree of abstraction words, as signs, allow.

The second stage of concept development Vygotsky referred to as "thinking in complexes" (L. S. Vygotsky et al., 1994, p. 218). At this point, compared to the first stage, the child has a greater ability to make objective connections between objects. Thinking in abstract signs (i.e. words), increases as each word now represents more than a separate entity, but begins to represent "family names" (1994, p. 221). By this, Vygotsky meant what was described earlier about the word "horse". The word now begins to mean all instances involving a horse, rather than just one specific horse the child happened to encounter. Thinking in complexes, however, is still a pre-adolescent characteristic because it falls short of what Vygotsky meant by a fully formed concept. Complexes are a lower form of cognitive functioning because they have flawed foundational underpinnings. That is, the interconnectedness of the ideas, although very real to the child, is based on subjective understandings. An example might be a child who believes all ocean dwelling animals are fish, including penguins (a bird) and whales (a mammal). This child is assigning just as much importance to the attribute "ocean dwelling" as she might "cold-blooded" or "warm-blooded" (if she was aware of these latter two). Developmentally, she may be at the pre-concept, complex stage where "there is an absence of any hierarchical connections and hierarchical relationships between attributes in complexes. All the attributes are basically equal in their functional meaning" (1994, p. 224).

Although complexes are pre-conceptual, according to Vygotsky, they bear a close enough resemblance to concepts that intelligible conversation between adult and child is

now possible.   The ensuing dialogue, then, provides a "powerful moving force" that

moves the child to the third and final stage of concept development (1994, p. 231). At

this point, the attributes associated with a complex have been "re-synthesized" by the

child, and words, playing the key role as a sign, allow for the highest form of abstraction

(1994, p. 250). As Vygotsky wrote about the difference between a complex and a

concept:

> the very distinction between complexes and concepts [is] due to the fact that one
> generalization is the result of the use of words, whilst in the other it comes into
> being as a result of an entirely different functional application of the same word.
> A word is a sign. (1994, p. 251)

Thus, the meaning of a word as part of a complex means something very different than

the same word as part of a concept. If we were to apply this to chemistry concepts,

perhaps the phrase "ionic bond" can be thought of as, for one student, representing one,

isolated positive ion attracted to one, isolated negative ion. But for a student thinking at a

more advanced level, they more accurately think of "ionic bond" as numerous positive

ions simultaneously attracted to numerous negative ions. The reason the former student

had an incomplete view of ionic bonding might not be simply due to lack of exposure to a

better representation of the concept. Rather, it might be that, developmentally, they are

not quite ready for the abstract thought required to comprehend particles no one has ever

seen (at least not "seeing" things in the traditional sense).

Two points of emphasis are worthwhile here. First, if indeed complexes are close

enough to concepts that they allow for effective communication between a more

knowledgeable other and a learner, this would appear to open the door for instruction in

the zone of proximal development. A chemistry instructor who recognizes a student

possesses a complex-like understanding of ionic bonding, can speak to the student in

advanced, yet accessible terms. That is, terminology that builds off the imperfect, but not entirely flawed perceptions the student currently holds, and at the same time stretches the learner's conceptual understanding to upper limits of the ZPD. Second, Vygotsky clarifies that when "adolescents do start thinking in concepts they don't abandon complexes" (L. S. Vygotsky et al., 1994, p. 252). Perhaps this sheds light on why students often cling to misconceptions "however much they conflict with scientific concepts" (Bransford, Brown, Cocking, & National Research Council (U.S.). Committee on Developments in the Science of Learning, 2000, p. 179).

So far, I have demonstrated that Vygotsky believed a new form of cognition occurs during adolescence; thinking in concepts. Rather than a quantitatively enhanced form of existing mental structures, "concept thinking is a new form of intellectual activity, a new mode of conduct, a new intellectual mechanism" (L. S. Vygotsky et al., 1994, p. 259). Further, I have shown that concept thinking employs signs. In particular, symbolic signs (such as words) that involve high degrees of abstraction. I've also suggested understanding abstract concepts is essential to understanding chemistry. Authors of chemistry textbooks touch on this in their introductory comments. Tro (2003) considers the sequencing of chapters to be critical, such as whether or not the highly abstract concept of electronic structure should come before or after an introduction to chemical reactivity, because "coverage of abstract topics too early in a course can lose some students" (p. xxi). Vygotsky's emphasis on words as signs is evident in Chang and Cruickshank's (2005) introduction, "At first, studying chemistry is like learning a new language. Furthermore, some of the concepts are abstract" (p. xxxii). Chemical education researchers Özmen, Demircioğlu, and Demircioğlu (2009) echo these sentiments by

suggesting "[t]he reasons for students' difficulties vary from the abstract nature of many chemistry concepts to the difficulty of the language of chemistry" (p. 682).

For the purposes of the current study, the most important aspect of the preceding discussion is Vygotsky's zone of proximal development. As noted above, it is consistent with all the major theoretical themes of this study, two of which I've highlighted already. That is, instruction in the ZPD is consistent with the notion that cognitive conflict is necessary for cognitive growth, and that medium level conflict is ideal. The ZPD is also consistent with the central theoretical perspective, that distributed scaffolding is best suited to promote medium cognitive conflict. Although the scaffolding metaphor, when first proposed by Wood, Bruner, and Ross in 1976, did not explicitly mention the ZPD or Vygotsky, subsequent literature has frequently made the connection (Stone, 1998). Further, the initial metaphor was framed as relating to dyadic educational scenarios, such as one parent with one child, and not incorporating multiples forms of assistance, such as from a teacher, peer, and computer prompts (1998). Nevertheless, the literature certainly implies Vygotsky would have encouraged distributed scaffolding. Mahn (2003) suggests that a Vygotskian classroom approach means "teachers should provide opportunities for the co-construction of knowledge through dialogic inquiry" (p. 134). And Gnadinger writes, "putting Vygotskian theory into practice means that classrooms must be places where social and verbal exchanges are commonplace throughout *all* aspects of the learning environment" (Gnadinger, 2001, p. 32; italics added).

I will now turn to the second major theorist who influenced the current study, Piaget. Vygotsky described some of Piaget's theories in his own writing, including spelling out contrasting ideas of the two men. Most notably was that for Vygotsky,

learning led development, and for Piaget, development led learning (L. Vygotsky, 2008). In spite of this difference, the following discussion will emphasize areas of convergence. That is, I will demonstrate that Piaget too felt cognitive conflict is necessary for cognitive growth, medium conflict is optimal, and distributed scaffolding best promotes a medium level.

Piaget. As noted above, Vygotsky and Piaget converged on cognitive conflict and its necessity for mental development (Niaz, 1995). Expressed in Piaget's own words, "faced with external disturbance, [a child] will react in order to compensate and consequently he will tend towards equilibrium" (Piaget, 2008, p. 23). "External disturbance" is another way of expressing cognitive conflict, and Choi, Land, & Turgeon (2005) use yet another term, one we've seen before, by suggesting that for Piaget, "knowledge re-construction is triggered by cognitive dissonance" (p. 483). As their phrasing implies, Piaget, like Vygotsky, was a constructivist. He believed children employ "continuous self-construction" and that knowledge is not just out there waiting to be acquired as is (Driscoll, 2005, p. 191).

Whereas Vygotsky believed cognitive conflict is best fostered when a more skilled mentor instructs a less skilled one, Piaget argued that it is most conducive to learning when *equals* scaffold each other (Rogoff, 1990). One problem with adults teaching children results from the unequal power status. The child in this case might simply accept what the adult says without critically considering it (1990). To the degree this is the case, I believe it might be especially relevant in chemistry. It is perhaps easier for a student to simply accept conceptually difficult content, and just try to memorize it, rather than take the considerable time necessary to critically evaluate it. Piaget felt that

the unequal adult-child partnership suffers from the potential that the child will practice "submission that can lead to mindless conformity in both moral and intellectual spheres" (DeVries, 2000, p. 203). Piaget also believed that peers were best suited to help students overcome situations in which they *perceived* a conflict to be of a low level, when in fact it wasn't. As we've seen before, if a child's interpretation of content is "overly personal and individualistic", a peer can help guide his/her fellow student toward a more accurate understanding (De Lisi, 2002, p. 7).

That said, Piaget qualified his stance by offering that an adult-child partnership can be fruitful *at times*. Earlier, I described the concept of intersubjectivity as a mutual, co-constructed problem solving event between two individuals. Intersubjectivity, it was suggested, was a characteristic of effective instruction within the zone of proximal development. Piaget would say *if* an adult can assume a stance that facilitates intersubjectivity, one in which the adult guides the learner as an equal rather than a subordinate, cognitive conflict can be successfully resolved by the learner. DeVries (2000) writes:

> Piaget contrasts the heteronomous adult child relationship with a second type that is characterized by mutual respect and cooperation. The adult returns the child's respect by giving her the possibility to regulate her behavior voluntarily. In so doing, the adult helps to open the way for the child to develop a mind capable of thinking independently and creatively and to develop moral feelings of reciprocity in all kinds of social relations. Obviously, children and adults are not equals. However, when the adult is able to respect the child as a person with a right to exercise his or her will, one can speak about a certain psychological equality in the relationship. (p. 209)

To better understand how Piagetian theory supports student learning at a medium level of conflict, regardless if an adult or peer serves as the more knowledgeable other, we need to first consider Piaget's stages of development. As with Vygotsky, the focus

will be on the final stage, that which coincides with adolescence, because it is here, according to Piaget, that an individual first develops the ability to reason abstractly and "imagine possibilities above and beyond current reality" (Driscoll, 2005, p. 198). That understanding chemistry requires understanding "beyond current reality", as if atoms and molecules were of a different world, is reflected in the title of the chemistry textbook used by the subjects in this study, "World of Chemistry" (Zumdahl, Zumdahl, & DeCoste, 2007).

Stages of development. Piaget proposed four stages of development. Sensorimotor (birth – approximately 2 years), preoperational (2 – 7 years), concrete operational (7 – 11 years), and formal operational (11 years onward) (Driscoll, 2005, p. 195; Piaget, 2008, p. 19). Two similarities to Vygotsky's stages are noteworthy. First, each stage represents a "qualitative change in children's cognition" (Driscoll, 2005, p. 194). That is, there is more than a simple quantitative expansion of existing mental structures. Second, just as Vygotsky believed that children don't completely abandon complexes once they start thinking in concepts, Piaget believed that "the more primitive structures of early stages are not lost as a child progresses to a later stage" (Driscoll, 2005, p. 194). Again, we see a potential theoretical explanation for why misconceptions among students are difficult to overcome.

Three of Piaget's four stages are labeled, in part, with the word "operational". It is necessary, therefore, to explain what he meant by the term. As described earlier, Piaget was a constructivist. He believed students are not blank slates who encounter something and make a mental copy of it as is. Rather, they "operate" on newly acquired knowledge by altering and transforming it as a means of making sense of it. An

operation is "the essence of knowledge; it is an interiorised action which modifies the object of knowledge" (Piaget, 2008, p. 20). Piaget suggests that an operation might be exemplified by putting things in a certain order, or by classifying in a certain way (2008). Perhaps in a chemistry class, a student first hearing about calcium hydroxide, $Ca(OH)_2$, might make the connection that since it contains the hydroxide ion, it must be a base because other compounds with hydroxide are also bases. In other words, the student operated on the knowledge by classifying it. As we will see shortly, this specific example would be a higher level, or "formal" operation, characteristic of his final stage because it dealt with abstract concepts.

Operations are also said to be reversible. Thus, if a child rearranges a row of marbles into a circle, a child at an operational stage will understand that the marbles can be transformed back into their original configuration (Driscoll, 2005). A connection with chemistry is straightforward in this case as well. All chemical reactions, in theory, are reversible, and practically speaking, many actually are. One example is the reaction of nitrogen with hydrogen to produce ammonia, $3H_2 + N_2 \rightarrow 2NH_3$. Under some conditions of temperature and pressure the reaction goes as written here. But under other conditions, ammonia decomposes to form hydrogen and nitrogen, just like rearranging marbles from the circle back into a row.

Another characteristic of operations is they have at least one constant property. A child employing operations, for example, will recognize that regardless of the arrangement of marbles, the number of marbles is invariant (Driscoll, 2005). In reversible chemical reactions, the total number of atoms involved in the reaction is constant, whether three hydrogen molecules (six atoms) react with one nitrogen molecule

(two atoms) to produce two ammonia molecules (eight atoms), or if the reverse occurs of two ammonia molecules (eight atoms) decomposing to form three hydrogen molecules (six atoms) and one nitrogen molecule (two atoms).

I will now briefly describe Piaget's four stages, emphasizing how operations change from stage to stage, and focusing on the importance of the abstract thought that develops in the fourth and final stage. In Piaget's first stage, sensorimotor, a child acquires foundational knowledge that serves as the "substructure" of the higher forms of thought to follow in later stages (Piaget, 2008, p. 20). A schema[5] develops for permanent objects, for example. In the preoperational second stage, symbolic thought emerges and the child begins to use signs (Driscoll, 2005; Piaget, 2008). For Piaget, this meant "they are able to mentally represent objects and events, as evidenced in their imitation of some activity long after it occurred" (Driscoll, 2005, p. 197). At this stage, however, there are no operations. Children do not mentally transform the objects and events they have encountered, and there is no reversibility as described above. Piaget's classic example of this is a child's lack of ability to realize conservation of quantity when a liquid is poured from one glass to another of different shape (Piaget, 2008). By approximately the seventh year, however, children enter the third stage, concrete operations, and it is at this point they begin to operate on objects, such as the example with marbles. They develop the ability, on a "concrete", non-abstract level, to comprehend concepts such as conservation of quantity and reversibility (Driscoll, 2005; italics added).

Beginning around 11 years of age, in the formal operational stage, the child

---

[5] Piaget used the word *schema*, which has been described as an organized cognitive framework. "[T]o interpret a particular situation in terms of a schema is to match the elements in the situation with the generic characteristics in the schematic knowledge structure" (Driscoll, 2005, p. 126; quoting Anderson, Spiro, and Anderson). In this paper, as in van der Veer (1994, p. 6), I will use the terms *schema* and *structure* (as in *cognitive structure*) interchangeably.

begins construction of "new operations, operations of propositional logic" (Piaget, 2008, p. 21). Propositions have been described as "the relationships among concepts" (Bruning, Schraw, Norby, & Ronning, 2004, p. 47), and Driscoll (2005) describes propositional logic as the "hallmark" of formal operations (p. 197). Thus, at this stage, children can begin to operate on, to consider the relationships among, more than just concrete objects. One result of this is enhanced problem solving skills. For example, in a chemistry-oriented experiment by Inhelder and Piaget, adolescents (formal operational) and younger children (concrete operational) were asked to combine clear liquids from four separate beakers until they found just the right combination to provide a yellow color. The concrete operational children employed an unsystematic approach, often repeating prior combinations. Interestingly, they also failed to consider combining three of the liquids, always choosing to mix two or four. On the other hand, the formal operational adolescents employed a more systematic approach, keeping accurate records of their trials, and, most importantly for our purposes, were able to hypothesize to guide subsequent steps (Driscoll, 2005). That is, their operations were abstract and no longer dependent on manipulation of a concrete object.

A point of emphasis is helpful here. It is quite possible that full utilization of formal operations does not occur until *late* in Piaget's final stage. For that matter, it has been suggested that some individuals, including scientists, never reach this level of thought (Driscoll, 2005). For example, a 12-year old is typically capable of dealing in mental abstractions of concrete objects. However, they generally are *not* able to establish mental *relationships* among each individual abstraction. That is, they would have considerably difficulty testing ideas "in their head" and "mentally sorting out possible

solutions, and systematically testing the most promising leads" (Biehler & Snowman, 1986, p. 63). An individual is likely to reach this level of cognition only much later in adolescence, if at all. Earlier, it was suggested that Vygotsky would likely agree that for an adolescent to understand chemistry, it requires development, not just learning. Here, we see evidence that Piaget might agree.

In our discussion of Piaget, I have so far highlighted three points. First, we were introduced to the fact that Piaget, like Vygotksy, believed that cognitive conflict was essential for cognitive growth. Second, I demonstrated that Piaget believed peer-to-peer interactions were more likely than adult-child at facilitating effective instructional events. Finally, we saw that the nature of operations plays an important role in the various stages of Piaget's developmental theory. What we have not covered, however, is the mechanism by which a child might progress through the stages. To address this issue, we will return to the concept of cognitive conflict. That is, when a child does experience conflict, whether involving operations or not, what general principles apply if an individual is to progress within a stage or from stage to stage? The Piagetian principles that address these issues are *assimilation*, *accommodation,* and *equilibration* (Driscoll, 2005).

Assimilation, accommodation, and equilibration. According to Piaget, we learn through the processes of *assimilation* and *accommodation* (Biehler & Snowman, 1986; Costu, Ayas, & Niaz, 2010; Driscoll, 2005). Assimilation has been described as "the process in which individuals *use their existing* cognitive structures to understand a new event" and accommodation as "*modification* of the current cognitive structures to interpret a new experience or situation" (Marusic & Slisko, 2012, p. 302; italics added).

It has been suggested that merely generating a conflict for an individual, rather than resolving it, leads to assimilation (Niaz, 1995). Assimilation has also been referred to as quantitative learning (Cress & Kimmerle, 2008) . Biehler and Snowman (1986) provide an example of a new first grade student adjusting to classroom routines. The current teacher expects students to line up in an orderly manner to receive materials. Since this is consistent with the expectations of the child's pre-school teacher, the child can assimilate the new routine into their existing cognitive structure. No restructuring is necessary.

To draw from a similar example used earlier, a chemistry student might believe that bases are compounds such as sodium hydroxide, NaOH, and calcium hydroxide, $Ca(OH)_2$, by nature of the fact that they have hydroxide in the formula. Therefore, if later encountering strontium hydroxide, $Sr(OH)_2$, the student will recognize the hydroxide in the formula and likely assimilate the new compound into their existing schema. In this scenario, the conflict generation involved seeing the new compound, $Sr(OH)_2$, for the first time. There was no issue to be resolved, however, because the student immediately made the connection to their prior knowledge and thus simply added the new compound (i.e. quantitative learning) to their knowledge base. Piaget himself described assimilation as "the integration of any sort of reality into a structure, and it is this assimilation which seems to me fundamental in learning" (Piaget, 2008, p. 26). It has been suggested, however, that such learning, while necessary, becomes problematic when schooling heavily favors assimilative over accommodative learning (Bransford & Schwartz, 1999).

Accommodation is a cognitive restructuring (Marusic & Slisko, 2012). This can occur only when learners have the ability to examine critically their existing beliefs

(Bransford & Schwartz, 1999). A cognitive conflict (or *disequilibrium,* to use Piagetian terminology) results when the learner recognizes that their new experience does not match their existing schema (Marusic & Slisko, 2012). Accommodative learning is considered more important than assimilative because when the individual resolves the conflict and returns to a *new* equilibrium, accommodation has a greater impact on cognitive development (2012). Accommodation can be illuminated by considering again the first grade student. In addition to recognizing familiar routines such as lining up, the student also must adjust to a first grade teacher who is more "businesslike" than the pre-school teacher (Biehler & Snowman, 1986, p. 59). The first grade classroom is now much more didactic then was the open, self-directed preschool room. Thus, the child must now accommodate their cognitive structure for the word "teacher" and come to new understandings of that individual's role.

The same applies to the chemistry student learning about what compounds constitute bases.   Having believed that compounds must have the hydroxide ion in their formula to be classified as a base, the student might learn the next day in class that ammonia, NH_3, is also a base. A cognitive conflict results since the formula doesn't fit the existing mental framework that bases are compounds with hydroxide in the formula. If cognitive development is to occur, and a new state of equilibrium reached (in the cognitive sense, this new state of equilibrium can be thought of as a *higher* state), the student is forced to restructure their current knowledge. Specifically, the student must now accept the notion that bases are defined more broadly. One such broad definition is that bases are compounds, which when dissolved in water, produce the hydroxide ion. This accommodation now allows for $NaOH$, $Ca(OH)_2$, $Sr(OH)_2$, *and* NH_3 to be classified

as a base. In other words, as a result of the restructuring, one could say that qualitative learning has occurred (Cress & Kimmerle, 2008; citation applies to the last sentence only).

Whether or not an individual assimilates or accommodates cognitive structures is governed by *equilibration*. Piaget suggests, "faced with external disturbance, [an individual] will react in order to compensate and consequently he will tend towards equilibrium" (Piaget, 2008, p. 23). A student then, faced with learning new concepts, in particular those which presumably generate cognitive conflict, is thrust into a state of disequilibrium, a state of mental "discomfort" which necessitates relief. Both children and adults, according to Driscoll (2005), exhibit a preference for using existing structures as often as possible. Perhaps assimilation simply requires less effort in order to reestablish equilibrium. In any case, for development to occur, such as the definitive changes associated with moving from concrete to formal operations, it appears that accommodation is necessary. "For children to make the transition between stages, cognitive restructuring (i.e. accommodation in response to disequilibrium) must occur" (Driscoll, 2005, p. 203). This is not to say that each accommodative event represents a transition to a new stage. If this were the case, the first grade student who restructured to accommodate the more businesslike teacher, and the chemistry student who accommodated to come to understand ammonia as a base, necessarily would have made a stage transition. This seems highly implausible. From a Piagetian standpoint then, it is perhaps best to consider successive, modest accommodations as, over time, leading to transformative cognitive growth, such as that associated with moving from concrete to formal operations.

Level of conflict and distributed scaffolding. There is no teaching technique, or set of techniques, that can claim to be *the* Piagetian method (Driscoll, 2005). Further, unlike Vygotsky and his zone of proximal development, Piaget has no one, well-known, conveniently labeled formulation explicitly featuring *medium* level cognitive conflict. However, if not overt, it is certainly implied. Piaget said, "learning is possible if you base the more complex structure on simpler structures, that is, when there is a natural relationship and development of structures and not simply an external reinforcement" (Piaget, 2008, p. 26). This implies a zone of proximal development type of learning environment. That is not to say it favors Vygotskian dialogue-based instruction between a teacher and a student, even one that fosters medium conflict. From a Piagetian perspective, "a learning environment should be created that encourages children to initiate and complete their *own* activities", so much so that even limited teacher intervention, such as asking leading questions in an inquiry-based setting, would be considered too coercive (Driscoll, 2005, p. 214; italics added). It would steer the child too closely to the "teacher's conception instead of allowing them to construct their own" (2005, p. 214).

Rather, Piaget's comment proposes a *self-directed* learning environment that creates conflict that *builds off* the students existing knowledge and developmental level. I will now make a case for why this necessarily refers to *medium* level conflict. Piaget emphasized the importance of diagnosis. That is, before designing the instructional setting, it is critical for the teacher to establish the child's baseline. If it is not known, excessively high cognitive conflict can result because "questions or experiences designed to induce conflict will only be effective when the logical structures on which they depend

have been or are being developed" (Driscoll, 2005, p. 216). A common chemistry experiment exists in which students are required to determine the amount of calories in a peanut. This can be accomplished in a crude but rather straightforward way by burning the nut and using simple laboratory apparatus to collect data. One way to assign this activity is a discovery based approach. Knowing only the basic equipment they will have available, students are asked to develop a hypothesis, including the variables to be tested, and then design a procedure to evaluate it (Holm & Travalglini, 2005). As shown earlier, it is only at the formal operational level that children can apply a systematic approach and think hypothetically (Driscoll, 2005). Therefore, from a Piagetian perspective, cognitive conflict is likely too high for early adolescents in this activity[6].

As for cognitive conflict which was too low, we have already seen evidence that Piaget believed it too was less than ideal. Piaget thought peers were best suited to help students overcome situations in which they perceived low cognitive conflict. If a child's interpretation of content is "overly personal and individualistic", a peer can help guide his classmate toward a more accurate assessment of the material (De Lisi, 2002, p. 7). In other words, low cognitive conflict, or even perceived low cognitive conflict, will not challenge the student enough to stimulate cognitive growth. In particular, it might considerably hinder the restructuring required for accommodation. Thus, when Piaget suggests that an "external disturbance" is necessary to move the individual towards a new equilibrium, the disturbance should not be too small or too great.

Finally, I will now also make the argument that Piaget would support at least some, if not all elements, of distributed scaffolding as defined in this paper. We have

---

[6] This is somewhat contradictory to the Next Generation Science Standards (Achieve, 2013). For example, it is recommended that engineering and technology be integrated into "classroom instruction when teaching science disciplines at *all levels*" (2013, p. 4; italics added).

already seen more than once that he believed collaboration amongst peers is well-suited for encouraging cognitive growth. As Driscoll (2005) writes about a Piaget-inspired classroom, "instructional strategies are favored that encourage peer teaching and social negotiation during problem solving" (p. 215). I am unaware of any evidence which suggests the social negotiation must be between only *two* children. Assuming a cooperative, mutually supportive group, it follows then that assistance from multiple peers is potentially beneficial. Further, it was described earlier that while an adult-child interaction is possibly problematic due to the unequal power status, Piaget certainly felt an adult who can "discuss things on an equal footing" with a child can be an effective teacher (DeVries, 2000, p. 203; quoting Piaget directly). Finally, although computer-aided assistance was not relevant until after Piaget passed away in 1980, nothing in the literature, to my knowledge, suggests he would oppose it. To the contrary, considering he favored instructional settings in which students "receive feedback from their own actions" (Driscoll, 2005, p. 214), he likely would support well-designed computer interventions which facilitated that.

Summary. I have demonstrated that Vygotsky and Piaget, although diverging at times on where their emphasis lies, nevertheless proposed respective developmental theories with significant confluence. They both advocated stage theories in which the final stage involves qualitative cognitive changes that, for the first time in an individual's life, allow for abstract reasoning. I have shown that both men explicitly felt that cognitive conflict is essential for development. To varying degrees of explicitness, they also shared viewpoints on the importance of a medium level of cognitive conflict and what amounts to distributed scaffolding (though they likely never used that exact term).

It is important to emphasize yet another similarity between the two theorists. That is, their respective bodies of work are primarily concerned with development and not instruction. Since the current study involves a 21st century *teaching* strategy, it is necessary then to review the literature from the standpoint of instruction. As Chaiklin (2003) suggests, "It seems more appropriate to use the term *zone of proximal development* to refer to the phenomenon that Vygotsky was writing about and find other terms (e.g., *assisted instruction, scaffolding*) to refer to practices such as teaching a specific subject matter" (p. 59; emphasis in original). For that reason, I will now turn to scaffolding.

Scaffolding. It is not surprising that a theory of development like the zone of proximal development might be linked with scaffolding. Vygotsky believed, after all, that a *more* knowledgeable other should guide a learner and Driscoll (2005) comments "this is consistent with the notion of scaffolding, where the instructor or more advanced peer operates as a supportive tool for learners" (p. 257). The origin of the scaffolding metaphor is generally attributed to Wood, Bruner, and Ross (1976), who suggest scaffolding involves a "process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted efforts" (p. 90). One manner in which a teacher might accomplish this is by "'controlling' those elements of the task that are initially beyond the learner's capacity, thus permitting him to concentrate upon and complete only those elements that are within his range of competence" (1976, p. 90). A point of emphasis needs to be, however, that effective scaffolding is assumed to result in more than just task completion. Rather, a "genuine change in understanding" occurs, such that, unlike the more familiar notion of a scaffold used for building

construction, the instructional scaffold would not be needed by the learner for subsequent attempts to accomplish the same task (Stone, 1998, p. 345).

   General characteristics of scaffolding. General features of scaffolding, as described in the literature, are mostly consistent, if not always described with the same terms. Wood, Bruner and Ross (1976) described six basic characteristics: recruitment of child's interest, reduction in degrees of freedom, focusing the child on the goal, emphasizing critical task features, controlling frustration, and modeling idealized solutions. Stone (1998) notes four commonly held features: "recruitment by an adult of a child's involvement in a meaningful and culturally desirable activity beyond the child's current understanding" with the assumption the "goal of the activity is understood and valued by the child", calibrated assistance, range of supports, and fading (p. 349). Others have mentioned shared understanding, ongoing diagnosis, calibrated support, fading, intersubjectivity, encouragement, and metered support (J.-R. Wang & Lin, 2009). As part of her dissertation *Scaffolding in Technology-Enhanced Science Education*, Wu (2010) performed a systematic literature review. She concluded that although numerous studies failed to even define scaffolding, those that did included one or more of the following five characteristics: support from a more knowledgeable other or tool, shared understanding of goals, monitoring student progress and adapting support accordingly, helping learner's accomplish tasks they would be otherwise unable to do, and gradually decreasing support. I will now take a closer look at the three most common themes: intersubjectivity (shared understanding), calibrated assistance, and fading.

   Intersubjectivity. As described earlier, in spite of one partner possessing greater content or skill knowledge, intersubjectivity requires other aspects of the learning

relationship be entirely collaborative. That is, the partners "collaboratively redefine the task so that there is combined ownership of the task and the child shares an understanding of the goal that he or she needs to accomplish" (Puntambekar & Hübscher, 2005, p. 3). Even if some task elements are beyond the child's current comprehension or skill level, shared understanding of the task is considered critical (2005). Kurtèn-Finnäs (2012) examined open investigations in a grade 7 first chemistry course in Finland (Swedish was the language of instruction). She found several examples of group "interactive processes and efforts to reach some kind of intersubjectivity" (2012, English abstract). She goes on to note "students 'ownership' of the investigations appears to have been important for their interest" (2012, English abstract).

Perhaps the primary benefit of intersubjectivity is that it "helps learners to bridge the gap between the levels of current and prospective knowledge" (Wu, 2010, p. 32) and this is particularly important "because an individual's knowledge is shaped by his culture and background" (p. 31 and 32). Emdin (2009) picks up this cultural theme and addresses intersubjectivity in urban science classrooms in particular. He is critical of accepted practices, and writes:

> In urban science classrooms, the issues that affect student agency are compounded by the rigid ways that scientific concepts and principles are presented and the focus on the dissemination of factoids generated by individuals that the students will never have access to or who they feel they cannot identify with. In a sense, the positivistic nature of school science combines with the corporate nature of science instruction and together, they create a hyper-rigid science classroom structure which predetermines the extent to which an escape from established constructions of who is the knower, learner, central figure, or outsider in the classroom can occur. (Emdin, 2009, p. 240)

He goes on to suggest that intersubjectivity can only be developed in urban science classrooms with "consistent dialogue with students, teacher, parents, and others about the

effects of structures in the classroom" (Emdin, 2009, p. 253). Stone (1998) underscored the importance of culture, and that a characteristic of scaffolding was that it was necessarily a "meaningful and culturally desirable activity" (p. 349).

Calibrated assistance. The second widely accepted characteristic of scaffolding is calibrated assistance. That is, continuously adjusted support, based on the results of ongoing diagnosis, which is provided throughout the learning activity (Puntambekar & Hübscher, 2005; Wu, 2010). This entails two aspects. The first is the need to assess the updated understandings of the learner; the second is to then offer revised support. Frequent dialogue between teacher and student is cited as a means of accomplishing ongoing diagnosis, similar to what occurs in reciprocal teaching (Puntambekar & Hübscher, 2005). Asking neutral, reflective questions not only allows the teacher to gauge where the child is at, it also facilitates learner metacognition. Such a face-to-face interaction between teacher and student, it has been suggested, is often preferable to computer-embedded diagnosis. Failing to appreciate the importance of metacognition, students often dismiss computer supports (Wu, 2010). I will return to more details on metacognitive scaffolding shortly.

In effective scaffolding scenarios, the ongoing assessment is always paired with revised support. Stone (1998) describes it as "carefully calibrated assistance at the child's leading edge of competence" (p. 345). In one study evaluating such support, the performance of three-year-olds on a puzzle activity was investigated. One group received assistance from their mothers, who were instructed to provide support as they deemed appropriate. A second group was scaffolded by one of the researchers. The support offered in this case was calibrated based on pre-determined prompts. Although

both groups made considerable gains in puzzle completion ability, improvement of the calibrated assistance group was significantly greater (Stone, 1998). Specific types of revised support include providing explanations, modeling idealized solutions, clarifying key points, and inviting greater participation (Puntambekar & Hübscher, 2005). Wu (2010) also suggests that the combination of ongoing assessment and revised support is vital for successful implementation of fading, the third common characteristic of scaffolding.

Fading. Fading, some researchers suggest, is the "defining characteristic of scaffolding that distinguishes it from other forms of support" (Wu, 2010, p. 26). As the term implies, support is *gradually* removed as the learner's knowledge and skill level increases. For a learner to eventually execute the task "autonomously", transfer of responsibility is passed along in a non-abrupt, measured fashion (F. Wang & Hannafin, 2008, p. 63). Once again, we see it is not surprising that scaffolding is often conflated with instruction in the zone of proximal development. Descriptions of the ZPD also emphasize withdrawal of support based on learner progress (Driscoll, 2005). Numerous benefits have been associated with fading. These include developing "higher cognitive abilities" (Wu, 2010, p. 43), "independent learning" (p. 1), as well as helping students "establish their confidence" (p. 5). Another key advantage of fading is that it facilitates the ability of the learner to generalize a task. That is, after successful scaffolding that includes fading, a student "abstracts the process" and can apply it to similar activities (Puntambekar & Hübscher, 2005, p. 3).

Throughout the literature then, scaffolding is consistently described as involving intersubjectivity, calibrated assistance, and fading. That is not to say researchers have

always taken all three factors into account in their analysis. In her literature review of

scaffolding in technology-enhanced science education, Wu (2010) found "the majority of

studies overlooked fading as a key feature" (p. 32). Further, only seven out of 56 studies

took a close look at the ongoing assessment necessary to provide calibrated assistance.

The other 49 studies "largely ignored" this fundamental characteristic (2010, p. 32).

Researchers also "tended to ignore the development of shared understanding

[(intersubjectivity)]", while, paradoxically, at the same time acknowledging its necessity

(2010, p. 31). For this reason, the analysis and discussion of the quantitative data from

this study, that which answers the first research question about differences in academic

achievement between the treatment and control group, will be informed by reflecting on

how intersubjectivity, calibrated assistance, and fading impacted student performance,

and how all fit under the larger umbrella of establishing a medium level of cognitive

conflict.

The second research question in this study is "what are the characteristics of

distributed metacognitive scaffolding when Latino high school chemistry students

collaborate on a quasi-natural wiki project?" Intersubjectivity, calibrated assistance, and

fading will also contribute to that discussion, but they will be more tangential than

primary. The qualitative analytic framework will focus, rather, on the related, but

broader theme of metacognitive scaffolding.

Metacognitive scaffolding. Finding aspects of intersubjectivity, calibrated

assistance, and fading in metacognitive scaffolding is not difficult. Metacognitive

scaffolding has been described, in part, as aiding students in connecting prior knowledge

with new ideas (Wu, 2010). This is consistent with intersubjectivity, which we described

earlier as helping students "bridge the gap between the levels of current and prospective knowledge" (2010, p. 32). Metacognition necessitates that learners evaluate strategy use (Kurt, 2007), thus metacognitive scaffolding would help accomplish this. The ongoing assessment, as part of calibrated assistance, would do the same. The gradual removal of support associated with fading could be applied to any aspect of metacognitive scaffolding. The purpose of this section, therefore, is to review the literature on metacognitive scaffolding, and then unpack how these and other characteristics fundamentally define it. Further, since it plays such a prominent role in the second research question, I will provide additional rationale for why *metacognitive* scaffolding, in particular, is a form of scaffolding worth investigating for a high school wiki activity.

Metacognitive scaffolding (MS) is less often referred to in the literature then metacognition itself[7]. I will touch on both in this section. Although the objective is to understand what fundamentally defines metacognitive *scaffolding*, descriptions of metacognition are, of course, useful. They highlight the characteristics intended to be internalized as a result of MS. MS is described as helping learners "recognize their knowledge and regulate their behaviors" (Wu, 2010, p. 39). Other descriptions have included the importance of assisting others with reflecting on goals, personal assessment, and coming to understand strengths and weaknesses (F. Wang & Hannafin, 2008). It has also been said to aid students in strategy selection, planning, and seeing multiple viewpoints of a problem (Wu, 2010). It helps learners not only make connections between current and prior knowledge, as stated above, but also between different phases of an activity (Puntambekar & Kolodner, 2005). In these descriptions, with terms such as "reflecting" and "planning", we begin to see two fundamental characteristics of

---

[7] For a quick reference for all acronyms used in this paper, see Appendix AA.

metacognitive scaffolding emerge: *recognizing knowledge gaps* and *knowing what to do about it*.

Definitions and descriptions of metacognition itself express these same themes. Manlove, Lazonder, and Jong (2007), for example, describe metacognition as "knowledge and regulation of [a learner's] own cognitions" (p. 142). Others describe metacognition as incorporating planning, organizing, self-awareness, monitoring, and evaluation of learning strategies (Kurt, 2007; Puzziferro, 2008). General self-knowledge has also been identified as an important element of metacognition. White (1999), for example, suggests metacognitive self-knowledge involves learner's having a firm understanding of their general strengths and weaknesses. Her focus was on distance learners, and she offers that metacognition among them was more than just recognizing a "failure of cognitions, but also [was] strongly directed toward a concern about how best to approach the learning units, and once underway, how best to proceed" (1999, p. 44).

Some authors distinguish between cognitive and metacognitive strategies, citing that cognitive strategies are related to learning, whereas metacognitive strategies "deal with how learning is monitored, organized and reflected upon as the process continues" (Jegede, Taplin, Fan, Chan, & Yum, 1999, p. 258). For our purposes, it is important to emphasize that these descriptions of metacognition are the ideal learning behaviors that MS would convey. In the broadest terms, once again we see that MS can be broken down into two fundamental characteristics. One is that it assists learners in *recognizing their knowledge gaps*, and two, it aids them in *knowing what to do about it*.

Why the emphasis on *metacognitive* scaffolding? That is, for a high school chemistry wiki project, what does the literature say about why it is important to

investigate how learners are aided in recognizing their knowledge gaps and knowing

what to do about it? Manlove and Lazonder (2007) suggest that employment of

metacognitive skills is especially poor among high school students. They assert that not

only do adolescents generally not realize when they do not understand something, they

are also poor at recognizing cues that point out shortcomings. Further, even for those

teenagers that do recognize knowledge gaps, they are still unable to articulate exactly

what it is they are confused about. Even the rare student who is able to overcome those

first two shortcomings often is still unaware of what to do about it. They lack "strategies

and tactics" for proceeding (2007, p. 144). That these high school students might

especially struggle with web-based learning has also been suggested[8]. In this case, of

which a wiki project would be an example, students are likely to visit internet sites in

search of answers. In doing so, they need to "quickly and critically evaluate both the

credibility and content relevance of a Web site for a given task" (S. K. MacGregor &

Lou, 2004, p. 163). Metacognitive skills are required to carry this out and it is unlikely,

given what is described here, that adolescents would generally possess these skills.

The literature suggests, then, that high school students, Latino or otherwise, might

exhibit poor metacognition in their learning tasks. Additionally, the various definitions

of MS (and adapted definitions of metacognition) can be distilled down to two

characteristics. That is, assistance that helps learners *recognize knowledge gaps* and

knowing what to do about it. This paper will proceed on these grounds.

Recognizing knowledge gaps. Recognizing knowledge gaps will be broken down

---

[8] For the purposes of the current study, web-based learning will be taken to mean integration of any online platform into the teaching and learning environment. Thus, web searches to find content for a report would classify as web-based learning, even if the mode of instruction was traditional. At the same time, an online course or blended course would be considered web-based learning as well.

into three distinct categories. This was reduced from four after data collection and analysis. The initial four categories were determined after reviewing the literature for commonalities among a variety of studies. These four initial categories can be described as scaffolding that aids or encourages a student in 1) monitoring what they have learned, 2) monitoring their learning strategies, 3) considering goals, and 4) making connections. However, because data coding revealed very few instances of *monitoring their learning strategies* (which dealt with *prior* learning strategies, as opposed to future), that was collapsed into one all-encompassing *strategy knowledge* category (discussed in more detail later in *knowing what to do about it*). Furthermore the taxonomy of the remaining categories was refined to make it more concise and reflective of the actual results. Thus, in the end, there were three categories for *recognizing knowledge gaps*. They are described as scaffolding that aids or encourages a student in reflecting on knowledge related to 1) content, 2) general goals, and 3) making connections. Respectively, they will be referred to as metacognitive scaffolding – content knowledge (MS-CK), metacognitive scaffolding – general goals knowledge (MS-GGK), and metacognitive scaffolding – making connections knowledge (MS-MCK).

Two key points are necessary to highlight about the descriptions of scaffolding which follow. First, the examples used are generally what one can do to support learners in metacognitive reflection (regardless if the intention of the scaffolder was to promote reflection). The degree to which these examples have been successful, however, is not considered here. Second, many of the examples identified in one category could also apply to another. For example, "In thinking about how it all fits together, we're confused about…" could just as easily support students in reflecting on making connections

knowledge, as it could on content knowledge. Therefore, categories are not mutually exclusive. As Wu (2010) indicates, "Although the purpose of taxonomies is to distinguish different kinds of scaffolding based on their function, in reality many scaffolds provide multiple functions simultaneously" (p. 40).

The first category is scaffolding that aids or encourages the student in monitoring *content knowledge (MS-CK)*. Other ways in which this is commonly expressed is helping students have increased awareness of their own learning, or assistance in reflecting on their learning. Wu (2010) describes how sentence starters can be used for this purpose. For example, "In considering how well this claim explains all the evidence, we think…" (2010, p. 21), or "In thinking about how it all fits altogether, we're confused about…" (2010, p. 23). In her own study evaluating early vs. late metacognitive scaffolding in middle school science classes, Wu (2010) asked metacognitive discussion questions such as "How long do the scientists believe the aerosols will remain in the air?", "How long do you think the aerosols will stay in the air?", "What did you conclude from the data?", and "Which hemisphere do you predict the volcanic cloud will affect?" (p. 127-128).

White (1999) investigated metacognitive knowledge among university foreign language distance learners. Students reflected on their metacognitive experiences with comments like "Spanish verbs are really difficult. I was making progress with everything else but they really held me back", "Eventually it occurred to me that I was having problems because verbs are hard and there is no single solution", and "I recognized the material and I should have known it, but I hadn't internalised it" (1999, p. 44). These comments, of course, represent metacognition, not metacognitive scaffolding. Thus, to be considered in this category of helping students reflect on their content knowledge, the

action of a more knowledgeable other would be akin to *prompting* these learners to consider how well they understood Spanish verbs or to what extent they internalized the content. Representative examples of helping students monitor content knowledge (MS-CK) are summarized in the first column of Table 1.

Scaffolding that aids or encourages students in monitoring *general goals knowledge* (MS-GGK) is the second category of *recognizing knowledge gaps*. This might entail "an expert [thinking] aloud about the problem" and focusing on "what he was trying to accomplish" (Wu, 2010, p. 24). Such a prompt might help the learner consider their own general learning goals. A question asked of a middle school science student near the end of their activity included "What science information did you find useful in answering the question?" (2010, p. 127). In doing so, the student presumably would need to focus on what the general goal of the activity was to determine what was useful and what wasn't. Sentence starters, such as the ones mentioned above, can also serve the purpose of getting students to focus on what they are trying to achieve (Wu, 2010).

The importance of metacognitive scaffolding geared toward helping students focus on general goals is underscored by the fact that different students engaged in the very same activity may have very different perceptions of what the primary objective is. White (1999) describes how some felt their main goal was assessment preparation, for others it was completing the units, others thought it was acquiring language skills, and yet another group felt it was to focus on problematic areas. Although these goals are related, they are nonetheless different. Further, only the last two seem to reflect the notion that *understanding* the content is an important goal, and none reflect general goals the teacher

Table 1

Examples of Metacognitive Scaffolding

MS-CK	MS-GGK	MS-MCK	MS-SK
Teacher prompts students to complete the following: "In considering how well this claim explains all the evidence, we think..." (Wu, 2010, p. 21)	Teacher or more knowledgeable other thinks aloud about what they are trying to accomplish. (Wu, 2010)	"What do you think are the implications of what you read?" (based on Jegede et al., 1999)	"Have you thought about studying in a quieter place with no distractions, such as the library?" (based on White, 1999)
Teacher prompts students to complete the following: "In thinking about how it all fits altogether, we're confused about..." (Wu, 2010, p. 23)	"What do you see as the main goal or outcome of this activity?" (based on White, 1999)	"What is your personal viewpoint about [insert concept]" (based on Kurt, 2007)	"You should try retelling the key points of the lesson to one of your classmates." (based on Kurt, 2007)
"Elaborate on your thinking about [insert concept]" (based on Wu, 2010)	"What science information did you find useful in answering the question?" (Wu, 2010, p. 127)	"What is your reaction to what we just discussed?"	"Have you considered working with the verbs in other ways?" (based on White, 1999)
Encouraging a student to use self-questioning and elaboration strategies. (Manlove et al., 2007, p. 143)	"What are you trying to accomplish with this task?" (based on Wu, 2010)	"Can you think of any comparisons between [insert concept] and your own life or the 'real world'?" (based on Kurt, 2007)	Encouraging a student or group of students to increase their effort.
"How long do the scientists believe the aerosols will remain in the air?" (Wu, 2010, p. 127)	"Why don't you focus on one unit at a time so you don't get overwhelmed?" (based on White, 1999)	"What past ideas can be linked to this new information, and how can they be linked?" (Thomas & McRobbie, 2001, p. 231)	"How might we construct an understanding of this concept?" (Thomas & McRobbie, 2001, p. 231)
"What did you conclude from the data?" (Wu, 2010, p. 127)	"Make a short-term plan for what you want to get accomplished today." (based on Kurt, 2007)		"Do you think there might be another way of approaching it that works better for you?" (based on White, 1999)
	"Record in your planner the hours you intend to work on the project this weekend." (very loosely based on White, 1999)		"Reflect on the strategies you've used to make sense of the sense of the topic of stoichiometry". (based on Thomas & McRobbie, 2001)
			"How successful do you believe it was repeating verb forms at different times during the day?" (based on White, 1999)

MS-CK = Metacognitive Scaffolding Content Knowledge, MS-GGK = Metacognitive Scaffolding General Goals Knowledge, MS-MCK = Metacognitive Scaffolding Making Connections Knowledge, MS-SK = Metacognitive Scaffolding – Strategy Knowledge

may need to highlight explicitly, such as learning to collaborate or developing 21st century skills. For the purposes of this study, these too are considered general goals.

Additional examples exist for how one might assist a learner in reflecting on their general goals. Kurt (2007) has described "making short-term plans for success" as metacognition related to organizing and planning. This might help a learner evaluate if their general goal for the day was to finish just one section of the text, or an entire chapter. Metacognition identified as knowledge of goals is represented by student comments such as "I find that I need to decide what I am going to study, or practice or complete before I begin" (White, 1999, p. 43). Although it wasn't classified explicitly as goal knowledge, the comment "I realised I had to set some goals for my study…I had to make sure I was going to learn something and that it would be useful" also represents a student focusing on outcomes (1999, p. 44).

Metacognitive scaffolding that encourages learners to reflect on their general goals might also involve a teacher encouraging a student, for a month-long activity, to set proximal goals for what will be accomplished by the end of each week. This could be helpful, for example, if the rubric called for completing a portion of the project within that time frame. Examples of metacognitive scaffolding that helps students consider general goals knowledge (MS-GGK) are found in the second column of Table 1. It is worth noting again that many of the examples in Table 1 could apply to more than one of the four categories. The examples in the table were used as general guidelines for the qualitative analysis which addressed the second research question. The assignment of categories depended more on the intent or the outcome, rather than the exact form of the MS.

The third and final category in *recognizing knowledge gaps* is scaffolding that aids or encourages a student to reflect on *making connections* (MS-MCK). This might be construed as applying prior knowledge to new situations, connecting different phases of an activity, and considering multiple perspectives. Kurt (2007) investigated the impact of online learning logs on activating the metacognition of distance learners. In the logs, a high percentage of students expressed their own views on course topics, reacted to the topics, and questioned the knowledge given in class. These are all described as statements expressing an "awareness of learning" (2007, p. 3). Additional examples that Kurt (2007) categorizes as "statements about monitoring learning" include a handful of students who agreed with the information provided in class and also those who made social comparisons (p. 4). In this case, the student statements represent their metacognition dealing with making connections, and the teacher's decision to implement the online learning log could be considered the metacognitive scaffolding.

Other studies tapped into the idea that metacognitive scaffolding could prompt students to make connections. One asked students if they "tried to think about the implications of what [they] read" (Jegede et al., 1999, p. 262). In another, adolescent chemistry students in Australia were reminded by the teacher to consider "What past ideas can be linked to this new information, and how can they be linked" (Thomas & McRobbie, 2001, p. 231). As a result, one student suggested they now considered how new content links to what she already knew. See the third column of Table 1 for examples of metacognitive scaffolding which is intended to prompt learners to reflect on making connections.

Based on my literature review, I have condensed metacognitive scaffolding into

two main themes: assistance that prompts learners to *recognize gaps in their knowledge*, and assistance which helps them *know what to do about it*. Regarding the former, we have seen examples of each of the three categories which comprise recognizing gaps (MS-CK, MS-GGK, MS-MCK). I will now discuss the second theme, *knowing what to do about it*, of which there is only one category, *strategy knowledge*.

  Knowing what to do about it. Metacognition that involves only consideration on what one has learned, or on what learning strategies have been used, or on other forms of reflection focused on the past, is considered incomplete. That is, it needs to be paired with assistance on what to do once gaps are identified (that is, focusing on strategy for the *future*). Initially, two common themes emerged from the literature related to this idea. They were scaffolding that aids or encourages a student to reflect on modifying their 1) *learning behavior* and 2) their *goals*. After the data collection and analysis, however, the latter was collapsed into the general goals category discussed above. Once the data was analyzed, there wasn't enough of a distinction between different goal categories to warrant multiple groups. Furthermore, the learning behavior category was retained, but renamed as *strategy knowledge*, and combined with the original *monitoring their learning strategies* category that was one of the original four categories from the major theme of *recognizing knowledge gaps*. In short, *strategy knowledge* is the only category to be considered in the main theme *knowing what to do about it*.

  Distributed scaffolding to assist students in reflecting on their *strategy knowledge* (MS-SK) takes several forms. For example, some suggestions might center on what a student should consider before beginning to study. In White's (1999) study of foreign language distance learners, she suggests a student comment that "it's important to look

through each unit to get an idea of what it's about…before you start studying in detail" is an example of metacognitive strategy knowledge (p. 42). Other students commented about needing "a quiet study space", "somewhere away from family", and "a good stretch of time – short stints are no good for me" (1999, p. 40). These were classified as metacognitive self-knowledge. Other examples of metacognition involved strategies one could employ as review, such as "retelling the lesson in detail" (Kurt, 2007, p. 4) or going back to "revise and consolidate" (White, 1999, p. 42). Metacognition related to strategy knowledge has also been described as "Asking questions about the content of the lesson" (Kurt, 2007, p. 5) or a student returning to what they had attempted previously, but this time realizing the need for "working with the verbs in lots of ways" (White, 1999, p. 44). What all these examples of metacognition have in common is they represent an adaptation of learning activities. Thus, metacognitive scaffolding would entail encouraging a learner to try such strategies, perhaps by suggesting "Have you considered working with the verbs in other ways?" As another example, for technology enhanced scaffolding, Wu (2010) suggests that an expert model tool usage within a computer program.

See the fourth column of Table 1 for representative examples of scaffolding that would aid learners in reflecting on strategy knowledge. Included in the table is an example of metacognitive scaffolding dealing with effort regulation. As noted earlier, web-based learning can be challenging for high school students for a number of reasons, one being they need to make relatively quick decisions about the veracity of web sites and whether or not time and effort should be allocated to certain content (J. T. MacGregor, 1992). Similar sentiments have been expressed about hypermedia in

general. Knowing "how much to learn, how much time to spend on it…and when to increase effort" is considered vital (Azevedo, Cromley, Winters, Moos, & Greene, 2005, p. 382). For the purpose of this study, amount of effort will be considered a strategy, and metacognitive scaffolding which encourages students to increase their effort will be categorized as such. Also in this category are suggestions to a learner to get them to consider new ways of constructing knowledge, as occurred in the Thomas and McRobbie (2001) study with Australian chemistry students. This message got through to at least one student, who commented, "Before, I think I focused on the physical aspect more than the mental aspect. Learning is not physically doing things: writing or listening. It is something that happens mentally" (Thomas & McRobbie, 2001, p. 239).

Additional metacognitive statements dealing with strategy knowledge from the White (1999) study of foreign language distance learners included, "I tried various things: spending the first part of my study time on verbs, repeating verb forms at incidental periods during the day, having conversations with myself focusing on using verb forms that I did know…None of these things made a dramatic improvement so I dropped them", and "for me, this more varied approach does work" (p. 44). Again, this represents metacognition and thus metacognitive scaffolding (i.e. MS-SK) would take the form of a teacher asking one of these students to "describe the various strategies you used to learn the verbs" or "how successful do you believe it was repeating verb forms at different times during the day?"

Similar sentiments are expressed in a study comparing metacognition in low and high achieving university distance education students. In that case, the questionnaire designed to probe student metacognition asked whether or not students "reflected on the

processes [they] used and the decisions [they] made" (Jegede et al., 1999, p. 262). In the

study of Australian Year 11 chemistry students using a construction metaphor to aid

metacognition, students were also "continually encouraged to reflect on their learning

process [and] to compare their processes with those suggested by the metaphor" (Thomas

& McRobbie, 2001, p. 231).

Summary. This section has provided examples of metacognitive scaffolding

(MS). Specifically, it was condensed into two major themes. Metacognitive scaffolding

that helps learners *recognize their knowledge gaps*, and metacognitive scaffolding that

assists them in *knowing what to do* about those gaps. The former theme has three

categories: metacognitive scaffolding – content knowledge (MS-CK), metacognitive

scaffolding – general goals knowledge (MS-GGK), metacognitive scaffolding – making

connections knowledge (MS-MCK). The latter theme (knowing what to do about gaps)

had only one theme: metacognitive scaffolding – strategy knowledge (MS-SK). The

examples were varied, ranging from recommendations to reflect on a particular learning

strategy, to specific suggestions related to goal setting. Examples also often apply to

multiple categories. They were used as *general* guidelines to structure aspects of the

qualitative analysis in the current study.

Interacting with all these examples, if scaffolding is to be successful, are the three

general characteristics of all types of scaffolding (not only metacognitive). That is,

intersubjectivity, calibrated assistance, and fading. That all of this would be difficult to

successfully incorporate and implement for one teacher, in a classroom full of 15-20

adolescents, for a conceptually difficult subject like chemistry, is probable. Such a

scenario is far removed from the original scaffolding dyad of one adult assisting one

young child in solving a puzzle (Wood et al., 1976). To alleviate this dilemma,

distributed scaffolding has been offered as an alternative.

 Distributed scaffolding. Earlier I described instruction in the zone of proximal

development as teaching slightly beyond a learner's competence (Rogoff, 1990), and that

this was equivalent to establishing medium cognitive conflict. One way to facilitate this

is to implement ongoing assessment of a learner's progress. This has been described as

essential for effective scaffolding (Wu, 2010). In the typical classroom, however, large

class sizes make evaluating each students moment-to-moment needs exceptionally

difficult (Wu, 2010). One way to try and alleviate this dilemma is through the use of

group work, where peers have the opportunity to scaffold one another. Another is by

implementing computer-based scaffolds. Concerted use of all three (teacher, peer, and

computer scaffolds) is the essence of *distributed scaffolding*. Wu (2010) suggests,

"studies should integrate multiple sources of scaffolding from teachers, peers, and

technology, and ensure the maximized learning effectiveness of each tool in a

complementary way" (p. 50). This study helps meet that need.

 Tabak (2004) described distributed scaffolding as incorporating "multiple forms

of support that are provided through different means to address the complex and diverse

learnings" that are associated with "disciplinary ways of knowing" (p. 305). Her

description is consistent with what Valanides and Angeli (2008) refer to as *distributed*

cognition. They investigated how a computer tool helped sixth graders learn about light,

color and vision. Moving beyond the concept of individual cognition, they situate

learning in a "social matrix" that includes tools and other individuals (2008, p. 310).

Drawing upon Vygotsky, they suggest that the collaboration which ensues amounts to

scaffolding in a learner's zone of proximal development. Their study involved primary school students, working in collaborative pairs, within the context of a computer-based problem-solving scenario about a stolen diamond. The pairs of students investigated the "crime", guided by computer-embedded scaffolds. This was then followed by a classroom discussion in which students presented their conclusions and received feedback. The researchers report the activity "positively affected students' understandings and promoted a lasting effect on their conceptions" (2008, p. 309).

Ironically, however, as is quite common in technology-enhanced science education (Puntambekar & Hübscher, 2005; Wu, 2010), the authors did not mention important scaffolding features such as calibrated assistance and fading. This is problematic because effective scaffolds theoretically need to be tailored for each learner. To the extent they are not, rather than being benign, they might actually impede a student's progress. For example, a student might have limited prior knowledge of a particular topic. A generalized, computer-based scaffold could, inadvertently, overwhelm the student. The scaffold might do more harm than good by "imped[ing] learning through cognitive overloading" (Wu, 2010, p. 34). Butler and Lumpe (2008) support this perspective:

> The scaffolds represented in the software are not the scaffolding features. They are the *interactions* seen between each feature and a particular student. For example, a scaffolding feature designed to help students organize information may only benefit students with poor organizational skills. Just because the feature is labeled a ''scaffolding feature'' does not mean it will scaffold the learning for all students. (p. 428; italics added)

Adding to this dilemma is the fact that students often require the *dynamic* scaffolding a human can provide in order to *effectively* use fixed scaffolds such as web resources and static computer-based questions (F. Wang & Hannafin, 2008; italics added).

Thus, because of large class sizes, complexities of each learner, and the need for ongoing assessment, among other reasons, distributed scaffolding has been offered as an improved means of providing assistance in certain learning environments.   Each level of interacting supports (teacher, peer, and computer), however, brings its advantages and disadvantages, some of which have been noted earlier in the discussions of Vygotsky and Piaget.

Peer scaffolding. Peers were described as potentially better able to assist a learner in negotiating cognitive conflict because of their status as equals (Rogoff, 1990). Children scaffolded by an adult authority figure, on the other hand, might accept without question what the adult had to say. Rogoff (1990) gives a specific cultural example, describing how Appalachian students might avoid asking the teacher a question in fear it might be viewed as an "impolite challenge" (1990, p. 129). Such deference to teachers might especially be the case in science classrooms, where Mortimer and Wertsch (2003) assert:

> with regard to science classrooms, the meta-contract underlying communication is based on the assumptions that (a) the teacher has clear, undisputed understanding of speech genres and the meanings of the terms he or she uses, and (b) the students' task is to try to understand and "master" these genres and terms. (p. 235)

Their primary point was that the ability to achieve intersubjectivity in science classrooms is compromised by the perceived "undisputed" superiority of the teacher.

Peer-peer interactions, on the other hand, are likely to lead to comments on a partner's logic as children feel "freer to examine the logic of arguments" (Rogoff, 1990, p. 174). The notion that a peer is better able to scaffold then a teacher is not limited to classroom contexts. Lave and Wenger (1991) offer that apprentices learn mostly from other apprentices in authentic settings. Small group settings, in particular, might be ideal

for facilitating peer scaffolding (Choi et al., 2005). "When learners receive critical and personalized questions from their peers, those interactions should prompt deeper reflection on and revision of their own knowledge" (2005, p. 488). In group discussions about the concept of evaporation, Costu et al. (2010) report that group discussions led students to alter their understandings toward a more scientific interpretation.

Perhaps the greatest advantage of peer over teacher scaffolding might be the ability for a student to relate culturally to her classmate. The opinion has been expressed that science education in particular suffers from disconnects between teachers and students from non-majority cultures (O. Lee & Luykx, 2005). Cultural artifacts and examples that would be familiar to nonmainstream students are often absent from science instruction. Teachers generally have trouble meshing standard scientific discourse with the home culture and language of diverse groups. For example, in urban neighborhoods, communicating orally has such high standing that it is often viewed as a performance. So much so that "the ability to use alliterative, metaphorically colorful, graphic forms of spoken language…is emphasized and cultivated" (Elmesky, 2003, p. 42).

Elmesky and Seiler (2007) describe one inner-city school in which it is not uncommon to observe students rapping, singing, and swaying as they walk, both in and out of classrooms. If such an activity were to occur in a chemistry classroom, such as a student creating a familiar rhythm while crushing tablets with a mortar and pestle, it might inspire a fellow student to begin humming or rapping to the beat, often unconsciously (2007). For our purposes, the primary point is that students often relate to each other in a manner the teacher cannot, and these peer relationships could promote more effective scaffolding. In such scenarios, teachers may even respond by reflexively

rebuking cultural expressiveness, considering only the student's dispositions as a liability, rather than first considering how to build from them (2007). The degree to which individuals relate to each other on a cultural level has been described as *cultural congruence*, a topic covered shortly in greater detail.

The preceding comments notwithstanding, peer interactions are often less than ideal, and frequently deleterious. The primary goal among peers might be simply to finish a project, rather than to learn (Rogoff, 1990). Generally, students are subject to more distractions than adults, and may be more concerned with "division of labor and social issues" (p. 163). For example, Anderson, Thomas, and Nashon (2009) reported on the collaborative nature of biology students working in small groups during field studies. Rather than embrace open discourse, which is needed to generate cognitive conflict and thus promote learning, students preferred to maintain social harmony at all costs. That is, if one student in the group reaches a conclusion about the science issue, and another student disagrees, the latter may prefer to keep quiet and not risk offending the former. Women in particular have been found to be more prone to these dilemmas. Gilligan (1993) concludes that women, although recognizing the need to take care of themselves (here, gaining as much as possible from the lesson), struggle at the same time with not wanting to damage relationships. Peer scaffolding, then, is not without its disadvantages.

Teacher scaffolding. We'll now turn to a critical look at teacher scaffolding. It has been said that creating learning environments that create conflicts for students, to the point where students generate questions to address contradictions, is a primary role of the teacher (Niaz, 1995). That a teacher might be better suited for this than a peer, especially for an abstract and conceptually challenging subject like chemistry, is likely, in my

opinion. For most, it takes years of studying and teaching chemistry to fully grasp the concepts. I believe these subtle understandings are essential in order to scaffold at a medium level of cognitive conflict.

Studies have supported this view. Adults have been shown to "promote more advanced planning strategies, provide more verbal instruction, and elicit greater participation then did child partners" (Driscoll, 2005, p. 258; citing the work of Radziszewska and Rogoff). In a study evaluating the effectiveness of using a construction metaphor to aid metacognition, two out of three Australian Year 11 chemistry students suggested the new strategy "could be easily discarded if it were not for the teacher's persistent reference to it" (Thomas & McRobbie, 2001, p. 254). In addition to the advanced content and pedagogical content knowledge, it has been said adults are also more likely to exhibit "greater sensitivity and demonstration skills" (Rogoff, 1990, p. 165). Acknowledging that peers, at times, may provide effective scaffolding, it is primarily for the reasons mentioned here in support of teacher scaffolding, that the hypothesis associated with the second research question asserts that teacher metacognitive scaffolding in the current study will be more effective.

At the same time, none of the additional experience and content knowledge of a teacher guarantees effective scaffolding, especially if their cultural background differs from students. Understanding the nuances of each and every student in a crowded classroom is impossible (Shulman & Wilson, 2004). The reasons for this are varied, and could include lack of instructional resources that illustrate diverse cultures, limited pedagogical knowledge of teaching nonmainstream students, or teachers' negative biases toward certain groups (O. Lee & Luykx, 2005). Even science teachers with cultural and

linguistic backgrounds similar to the students may struggle, including those with strong

content knowledge (2005). Therefore, mismatches in communication styles and cultural

backgrounds might lead to unsuccessful interactions between science teacher and student,

and, from the student's perspective, generate negative feelings about the discipline the

teacher represents (Elmesky & Seiler, 2007).

Computer-based scaffolding. Not surprisingly, computer-based scaffolds, with

the potential to offer dynamic interactivity and multi-modal experiences, can potentially

be effective. As noted above in a study with primary school students, to a certain degree

the computer scaffolds were able to support student learning by guiding investigative

inquiry (Valanides & Angeli, 2008). More often than not, however, technology-

enhanced computer scaffolds in science education fall short of faithfully executing the

scaffolding model. For example, in only one of 56 studies reviewed by Wu (2010) was

the computer scaffolding designed to both evaluate each learner's performance and, then,

fade accordingly. Further, computer-embedding fading that does exist can be

problematic if poorly implemented, such as the scenario that occurs when fading is pre-

planned and occurs at moments when some learners are not yet ready to proceed (2010).

It is worth emphasizing again that "in the absence of interaction between a more

knowledgeable individual and a learner, computer-embedded scaffolds cannot

sufficiently ensure that students internalize the information being presented" (2010, p.

46).

Summary. To conclude this section on distributed scaffolding, I assert that

optimal learning occurs when a proper balance is struck. To return to the overarching

theoretical framework of this study, that is, cognitive conflict, I believe distributed

scaffolding will help foster it at the medium level. As discussed above, peers are often better able to relate to the lived experiences of their classmates. That is, compared to the teacher, adolescent peers very likely have considerably more cultural interconnectedness. There is the chance, however, that due to their lack of experience with abstract concepts, peer mentor understandings are superficial, and their grasp of the concepts involves one or more alternative and nonscientific conceptions. The danger in this, of course, is their explanation to their classmate will not only be inaccurate, but it might be phrased in such a way that appeals to both their and their classmate's level of understanding. In other words, both students *perceive* low cognitive conflict.

At the other extreme, there might be a student who indeed does "catch on". In spite of the conceptually difficult content, for whatever reason, they more or less have a handle on it. What they might still lack in this case is a thorough understanding of the "big picture". That is, how does this particular topic fit in with the other concepts in the course? And with a lack of pedagogical content knowledge, they do not have a sense of how to bring a peer from where they are to where they need to go, conceptually. In scenarios such as this, the danger in peer scaffolding lies in high cognitive conflict. Stated in Vygotskian terms, in this case the peer mentor may tutor beyond the peer learners ZPD. So whether the peer goes above the learners ZPD (high cognitive conflict) or near the bottom (low cognitive conflict), we come back to the notion that an experienced teacher is needed to mediate the collaborative learning to guard against either extreme (Marusic & Slisko, 2012).

In a similar manner, peers also contribute positively to this checks and balances system. For teachers, I propose that the high cognitive conflict pitfall poses the biggest

threat. That is, even in the best case scenario where they relate well to their students, teachers are prone to scaffolding beyond a student's ZPD. This might occur for two reasons. One deals with prior knowledge having considerable impact on learning. It has been suggested that effective teachers have a good understanding of students' preexisting conceptions (Costu et al., 2010). Therefore, if a teacher does not have such understanding, they may have a sense of where the student needs to go conceptually, but they have no idea where they are starting. Thus the teacher, with well-developed, abstract schema of their own, will likely scaffold, unintentionally, well above the head of the learner. Even in the case where the teacher does have a sense of the student's prior conceptions, it still may be difficult for them to come down conceptually to the student's level. In either of these high incongruence conditions, a peer might be more likely to recognize the source of confusion more so than the teacher. This might occur because of similar cultural backgrounds. This cultural "harmony" is the subject of the final section of the multifaceted theoretical framework.

Cultural congruence. Stone (1998) emphasizes scaffolding does *not* take place in a "cultural vacuum" (p. 354; italics my own). The subjects in the current study are Latino high school chemistry students in an urban public charter school in a major Midwestern city. For this reason, a piece of the theoretical puzzle will include cultural congruence[9]. That is, instruction in a manner congruent with the culture of the students. The importance and implications of this have already been touched on, such as noting that peers might culturally relate better to their classmates than a teacher would (Elmesky

---

[9] *Congruence* in this sense, as in *cultural congruence*, or it's negative, *cultural incongruence*, does not necessarily overlap with incongruence as described earlier, as in teaching at a level of *medium incongruence*. The former deals with culture, the other describes cognitive conflict. However, it is possible that cultural incongruence might contribute to greater cognitive conflict. For example, as described earlier, a teacher might use examples familiar to some, but less so to nonmainstream students.

& Seiler, 2007), and that scaffolding was effective only if "meaningful and culturally desirable" (Stone, 1998, p. 349).

Numerous other scholars have addressed the theme of meaningful instruction, often with an emphasis on culture. It has been suggested that instruction and assessment should build off the everyday experiences of students, and that it "cannot be meaningful without incorporating the student's system of meaning and understandings" (Orosco, 2010, p. 266). The importance of including assessment along with instruction was also emphasized by Bransford et al. (2000), who state that an effective teacher will "assess students' abilities to link their current activities to other parts of the curriculum and *their lives*" (p. 140; italics added). O. Lee and Luykx (2005) suggest that learning is simply not possible when it is not "linguistically, culturally, and cognitively meaningful" (p. 417). Also emphasizing the importance of drawing from student experiences, Delpit (2006) writes the "teacher cannot be the only expert in the classroom" (p. 33). Ausubel is perhaps best associated with the expression "meaningful learning". Although culture was not the primary emphasis of his theory, he believed it was necessary to account for it, just as you would any other factor that influences a child's preexisting cognitions (Driscoll, 2005, p. 125).

As was noted earlier, the threat of cultural incongruity is perhaps greater in science classrooms. We have already seen that establishing intersubjectivity in science might be especially difficult (Emdin, 2009; Mortimer & Wertsch, 2003). Teachers are often perceived by students as the holders of privileged knowledge, that which is prohibitively beyond their own experiences. It is also often difficult for nonmainstream students to relate to standard patterns of scientific discourse (O. Lee & Luykx, 2005). It

has been suggested, then, that science teachers should take pains to develop novel

approaches of bridging the communication divide. Tapping into the movement

expressiveness of inner city African American students, for example, has been described

by Elmesky and Seiler (2007):

> As students generate a sense of belonging in science class through practices unrelated to science learning, their hybrid identities can expand to include being participants in science activities. These analyses point to the importance of developing planned and spontaneous approaches to curriculum enactment in which students can feel increasingly connected to science learning activities through movement expressive practices or other dispositions that are part of their identities. (p. 90)

Butler and Lumpe (2008) interpret the National Educational Technology Standards,

which emphasize the need to "facilitate learning of relevant content while addressing

individual needs", as a call to design learning environments that permit students to

construct knowledge based on their own experiences (p. 428).

Finally, I have already described language as a sign system which Vygotsky

considered central to learning abstract concepts. He felt the use of words as signs

"provides for decontextualization" and permits us to make sense of concepts far removed

from "concrete context" (Driscoll, 2005, p. 259). This suggests that to the degree the

students in the current study are English language learners, English being the language of

instruction, significant achievement barriers would exist. For this reason, the study was

designed to allow students to use Spanish as needed to communicate and develop drafts.

The only language restriction was that their final product would need to be in English.

Further, in order to tap into their "funds of knowledge" (Gonzalez et al., 1995), students

were explicitly requested to be creative and explain chemistry concepts by drawing from

their own backgrounds and cultural experiences.

Summary. We have seen how the theoretical framework of this study draws upon multiple perspectives. The developmental theories of Vygotsky and Piaget were discussed, with emphasis on how they might impact high school students learning chemistry. It was suggested that for an adolescent to learn abstract concepts, development was necessary. Learning scenarios that promote medium cognitive conflict were said to foster this development. Putting this into practice was described as best achieved through distributed scaffolding. Special attention was paid to metacognitive scaffolding, as metacognition among high school students is considered to be poor, and in need of further study. I noted how the theory of cultural congruence influenced activity design.

The first research question in this study asks if a difference exists between a treatment and control group when the former participates in a collaborative wiki project. The second question deals with describing the nature of the metacognitive scaffolding for such an activity. It is not coincidental that the central, binding assertion of this study is that distributed scaffolding (metacognitive or otherwise) is best suited to promote medium cognitive conflict. It is believed the wiki platform is ideal for facilitating such scaffolding. I will now turn to the final two sections of the literature review. These deal with science education, and with educational wikis.

Related Science Education Literature

Quasi-experimental high school chemistry studies. Three quasi-experimental studies dealing with adolescents learning chemistry influenced the design of the current study. The subjects of the first study were described as Year 11 high school chemistry students in rural Iowa (Hand, Yang, & Bruxvoort, 2007). Most instruction on a

stoichiometry unit was the same for both treatment and control group, including

laboratory activities, and assigned problems. At the end of the unit, however, the groups

diverged. Treatment students met in small groups to discuss unit concepts. The teacher

offered assistance as needed. Each student then wrote a letter to younger Year 7 students

explaining the key concepts. The seventh graders read the letters, provided feedback on

what was understandable and what wasn't, and the chemistry students then made

revisions accordingly. The control group, on the other hand, had the more traditional

approach of chapter summary and additional end-of-chapter problems.

Analysis was both quantitative and qualitative. As with all three quasi-

experimental studies to be discussed in this section, a pretest was administered solely for

the purpose of establishing equivalency among groups. That is, once no significant

difference among treatment and control was determined, the pretest scores were not used

in subsequent analysis. The reasons for this are not explicitly stated but might be due to

the lack of reliability of both pretest and gain scores, two issues which will be discussed

in more detail in the methods section of this paper. The posttest scores, evaluated both by

question (or set of questions) and overall score, demonstrated a significant difference

between treatment and control on only one of the questions. Interestingly, it was the

most conceptual and least quantitative question where the difference was found. Cohen's

d effect size was 0.61 for the statistically insignificant mean difference for the overall

score. Qualitative analysis, based on semi-structured interviews of selected students,

revealed that writing letters to the younger students prompted deeper consideration of

concepts. The high school students had to use language in the letters that would be

understandable to chemistry-naïve seventh graders.

The subjects of the final two quasi-experimental chemistry studies were Turkish adolescents, one a group of tenth-graders from Ankara, the other eleventh-graders from an unspecified locality. In the latter case, Özmen, Demircioğlu, and Demircioğlu (2009) evaluated the impact of conceptual change text (CCT) and animations on helping students overcome alternative conceptions of chemical bonding. Over the course of a unit that included several bonding related topics, students read and discussed CCTs and interacted with related computer animations. Unlike the Hand et al. (2007) study, the intervention was spread out over much of the unit rather than being review oriented. As this was occurring, the control group received "teacher-centered", "talk and chalk" type lessons in which they completed worksheets, received feedback, and had opportunities to ask questions (Özmen et al., 2009, p. 686). Similar to the Hand et al. (2007) study, comparison of pretest scores found no significant differences between treatment and control (Özmen et al., 2009). An independent means t-test did, however, find a statistically significant difference in posttest scores, with treatment outperforming control. Cohen's d was 0.59. Further, results of a delayed posttest indicated that while the scores of both groups declined relative to the original posttest, the drop for the treatment group was significantly less. This final statistical test was an ANCOVA with the original posttest scores used as covariate.

The second Turkish study also evaluated the impact of CCT, this time with analogies, to help students overcome alternative conceptions related to acids and bases (Çentıngül & Geban, 2011). The method is described as students reading a segment of the CCT and then pausing after key paragraphs for class discussion. A feature of these CCT, in addition to activating student misconceptions and presenting evidence to

counteract them, was analogies. For example, in order to address the common misconception that acid strength increases with the number of hydrogens in a particular compound, a light bulb analogy was used. HCl is a stronger acid than H_3PO_4, in spite of having only one hydrogen in the formula, because it provides more hydrogen ions to the solution when dissolved. Similarly, a single light bulb is potentially capable of providing more light then two or more light bulbs.

The article implies that treatment students used several CCT over the course of an entire unit. During this time, control students received instruction that was teacher-centered and did not address common student misconceptions. As noted above, these researchers also used pretest scores to establish equivalency among groups. After treatment, using the covariate of students' science process skills (determined by another instrument), an ANCOVA revealed the treatment group significantly outperformed the control group. Cohen's d was a very high 1.73.

Chemical education literature featuring student creativity. Instruction lacking cultural congruity is potentially problematic, as was described earlier. Science classrooms, in particular, were identified as places where nonmainstream students feel a sense of disconnectedness. One means of alleviating this is to have students draw upon their funds of knowledge (Gonzalez et al., 1995). That is, allow them to be creative in ways that are personally meaningful. To a limited extent, chemical education literature has addressed this. Novel teaching approaches have been used, such as encouraging students to create jingles (Heid, 2011), poetry (Bertholdo, 2006), element autobiographies (Stout, 2010), and limericks (Alber, 2001). Stout (2010) describes that simply encouraging students to be creative with their writing was not sufficient. It wasn't until

he read a creative story from the literature about the element lead, one that involved a

family of lead prospectors from the Middle East in search of lead ore, that students got

the message that creativity was not only acceptable but often a preferable way to learn

about chemical and physical properties of elements. Unfortunately, what all of the above

cited papers have in common is that they are descriptive, not experimental. In the current

study, student creativity will be explicitly encouraged and rewarded and be an integral

part of the quasi-experimental design.

Wiki and Related Literature

     Medium incongruence, individual learning, and knowledge building. The

notion of cognitive conflict was introduced earlier by providing an example of a wiki

study (Moskaliuk et al., 2009). College students read a number of pamphlets on the

various causes of schizophrenia, after which they were presumed to have equivalent

knowledge of the topic. They were then asked to individually develop wiki pages which

would convey their newfound knowledge to "real" patients and families. Three

conditions existed, however. Some wikis were prepopulated with content from all the

pamphlets (low incongruence), some from half the pamphlets (medium incongruence),

and some had no prepopulated content (high incongruence). After building their wikis

from these respective templates, students in each group took a post-experiment

questionnaire. They were asked to indicate if various statements about the causes of

schizophrenia were correct or not. Consistent with the researcher's hypothesis, the

medium incongruence group scored significantly higher on this "factual knowledge" test

than both their low and high incongruence counterparts (2009, p. 557). Furthermore, a

significant difference in favor of the medium group was also found for "conceptual

knowledge" (2009, p. 558). In this case, conceptual knowledge was measured with an open-ended question asking students to provide their best explanation for the causes of schizophrenia.

Moskaliuk's collaborators, Cress and Kimmerle (2008), suggested the theoretical model behind the aforementioned study. They expand the Piagetian concepts of assimilation and accommodation so they apply not only to individual learning, but also to knowledge building on the wiki itself. They describe the interconnecting of individual learning (internal, cognitive) and knowledge building (external, wiki based) as a "co-evolution" of cognitive and social systems. The individual learning aspect is consistent with the descriptions of assimilation and accommodation covered earlier. That is, internal assimilation is quantitative individual learning and internal accommodation is qualitative individual learning. Their broader view, however, now includes external assimilation (quantitative knowledge building) and external accommodation (qualitative knowledge building). More specifically, external assimilation amounts to adding new information to a wiki without reorganizing or connecting existing content (Moskaliuk et al., 2009). External accommodation, however, involves "rebuilding or restructuring existing content to make new information compatible, or connecting different pieces of information" (2009, p. 558). Cress and Kimmerlee's model suggests that operationalization of these four processes occurs when an incongruence exists between an individual's knowledge and the content on the wiki. Interestingly, this team of researchers also found a correlation between acquisition of factual knowledge and assimilative knowledge building, as well as between the acquisition of conceptual knowledge and accommodative knowledge building (Moskaliuk et al., 2009).

Peer collaboration. Unlike the Moskaliuk et al. (2009) study, most wiki research is qualitative in nature. Several themes have emerged, not the least of which is that effective collaboration among group members is far from assured. This is not surprising considering what we saw earlier about peer interactions often being less than ideal. L. Lee (2010), in describing her wiki intervention with beginning college Spanish students, noted students specifically asked for "guidance to assist them in the peer-editing process" (p. 271). Further, she asserts that "the instructor should constantly monitor the editing process" to ensure effective peer collaboration (2010, p. 271). Even students who embrace group activity might still prefer to divide up tasks (cooperative) as opposed to working together (collaborative).   This has been observed in another study and the researchers speculate their grading scheme might be to blame, in part (Alyousef & Picard, 2011).

L. Lee (2010) notes that some students will not want to surrender individual title to their work. She goes as far to suggest that wikis may generate "aggressive attitudes and feelings of discomfort" (2010, p. 261). Similar notions have been described elsewhere. Some students, it has been demonstrated, prefer independent work. They do not like others editing what they contributed (Reich, Murnane, & Willett, 2012c). Relatedly, some prefer not to edit someone else's effort. Multiple wiki researchers, studying multiple disciplines, from a language arts methods class (Matthew et al., 2009), to a German mythology course (Lazda-Cazers, 2010), to an elementary Spanish course (L. Lee, 2010), all suggest students are often hesitant to make edits for fear of "stepping on someone's toes".

What can a teacher do then, to minimize the impact of these potential threats to

effective wiki collaboration? Lund (2008) has suggested that schooling has historically been an individual endeavor and that "such an inheritance is not easily discarded or transformed" (p. 50). Thus, an aggressive approach toward team building seems essential. Jeong (2012) evaluated the order in which collaborative events took place, such as initial postings and edits. His findings suggest that one student editing another student's work might be triggered by first having the first contributor perform a self-edit. In essence, this might signal to other group members that making a change is welcome. Vallance, Towndrow, and Wiz (2010) suggest that online collaboration, wiki or otherwise, is most effective when students have first developed "face to face working relationships" (Vallance et al., 2010, p. 20). This notion has been supported by others. L. Lee (2010) had students initiate their wiki projects by meeting with their teams to organize ideas and assign initial tasks.

It has been noted that success on collaborative projects, in general, is dependent on group harmony. Dysfunctional interactions, unfortunately, require "participants to direct their cognitive efforts to an analysis of the interactions rather than the academic content" (De Lisi, 2002). To get past this, instructors need to discuss with students the "nature of…small cooperative groups", which presumably means to share the benefits, as well as provide strategies for overcoming potential roadblocks (Basili, 1988, p. 96). Benefits that can be shared include honing listening and communication skills, promoting deeper understanding of content, and a general perspective that it is important to treat other group members with respect, even though they may have different opinions (De Lisi, 2002). Johnson and Johnson (1999) suggest emphasizing for students "positive interdependence and individual accountability" (p. 69). Improved writing has also been

cited as the offspring of collaborative work when students work together to "summarize, question, and clarify" (Jeong, 2012, p. 1). If for no other reason, working with others offers the likelihood they might notice mistakes the original author missed (Rogoff, 1990).

Checkpoints. Generally speaking, proximal goals are more likely to be met than distal ones (Driscoll, 2005). Rogoff (1990) described how skilled mentors create subgoals and segment complex problems. She goes on to describe how the Guarenas in Venezuela, when instructing apprentices, create subgoals when teaching cultivation and animal husbandry. Successful wiki projects have been described in a similar manner. Over a range of content areas, checkpoints were established in for a variety of tasks (Evans & Moore, 2011; L. Lee, 2010; Matthew et al., 2009). For example, students might be required to contribute their first wiki content within the first three days of a three week project.

Templates. In a usage analysis study of K-12 public access wikis, Reich, Murnane, and Willett (2012a) found a trend that suggests the early life of a wiki, meaning in this case the first two weeks, is very important. That is, a high quality wiki is more likely to develop if considerable development takes places immediately after initial creation. Thus, the researchers conclude "if great wikis are recognizable soon after creation, then educators should invest scarce time in establishing effective site architecture and communal norms early on" (2012a, p. 2). Echoed in these sentiments is not only the theme of the teacher facilitating collaborative work, but also the importance of creating templates for students to work from. Although using different terms such as preformatting, providing template pages, or establishing an organizational structure, other

researchers also emphasize the importance of templates (Larusson, 2009; Matthew et al., 2009).

      Idealized versions. Providing an idealized version has been suggested as sound pedagogy, for wikis or otherwise. I described this earlier as a fundamental characteristic of scaffolding (Puntambekar & Hübscher, 2005; Wood et al., 1976). Adults should provide an idealized version when scaffolding young children (Rogoff, 1990). Liberian tailors, during their apprenticeship, first begin learning how to *finish* the product so they get an immediate sense of the big picture (Lave & Wenger, 1991). New Alcoholics Anonymous members hear, early on, the old-timers telling their "polished" stories so they too will quickly learn how to share their struggles (1991, p. 82). Turning to wikis in particular, example pages were provided in both a computer science wiki activity (Larusson, 2009) as well as an organic chemistry one (Evans & Moore, 2011).

      Spelling out the benefits for students, establishing checkpoints, providing templates and idealized versions, have all been suggested as means of facilitating an effective wiki project. These all were incorporated into the wiki design in the current study. Further details, and other issues of methodology, will now be discussed in the next chapter.

Chapter 3: Methodology

Review of Research Questions

Two research questions frame this study. They are:

Research Question 1:	Is there a difference in academic achievement between a treatment and control group on selected concepts from the topics of bonding, physical changes, and chemical changes, when Latino high school chemistry students collaborate on a quasi-natural wiki project?
Hypothesis 1:	As measured by posttest scores, the academic achievement of the treatment group will be greater than that of the control group.
Research Question 2:	What are the characteristics of distributed metacognitive scaffolding when Latino high school chemistry students collaborate on a quasi-natural wiki project?
Hypothesis 2:	The teacher will be more effective than peers at facilitating metacognitive thinking in learners.

Instrumentation

Development of pre/posttest. In order to answer Research Question 1 and quantitatively evaluate the impact of the wiki activity, an instrument needed to be developed.   Topics for the activity and the accompanying instrument were selected for two main reasons. First, a review of the literature revealed topics that addressed student alternative conceptions in chemistry. When a particular topic from the literature

coincided with school and state objectives, the topic was given strong consideration for inclusion. Second, the topics had to coincide with the course objectives for chemistry at Metro[10] High School, as well as those mandated by the state.

Literature search. The literature was reviewed to identify common alternative conceptions among chemistry students. The search was initially geared toward the high school level (or the rough international equivalent), but was expanded to college to provide a broader survey. Further, special attention was given to studies which provided access to validated questions. The validation procedure varied from study to study. Details of the validation for each question will be described below, but a brief mention of two studies mentioned previously will paint the general picture.   In the study which evaluated the impact of conceptual change texts and animations on helping students overcome alternative conceptions of chemical bonding, the author prepared the questions and a total of 12 individuals, described as either chemistry educators or experienced chemistry teachers, reviewed the questions for content validity (Özmen et al., 2009). In another study, the questions were developed by the researcher and then pilot tested, modified, and also examined for content validity by three chemistry educators (Çentıngül & Geban, 2011).

The studies were tracked down by three primary means. The first source was the ERIC (from Ovid) database. The second was either a general Google or Google Scholar search. In both of these first two cases, a trial and error use of chemistry, chemical education, and science education related search terms was used until a sufficient number of papers were located. Finally, once a handful of articles had been reviewed, the bibliographies of these papers were hand searched, leading to the retrieval of numerous

---

[10] Pseudonyms used throughout for the name of the high school and names of individuals.

other papers.

    Discussion with teacher. After an extensive review of the literature, and organizing potential questions by general chemical concept, I met with Jody, the teacher for all three participating chemistry sections. She reviewed 10 sets of questions, each with roughly 5-10 questions, and each on a particular theme including ionic bonding, chemical reactions, particulate nature of matter, physical changes, molecular representations, elements, covalent bonding, ions and ionic formulas, conservation of matter in chemical changes, precipitation reactions, atoms, mixtures, and characteristic properties. After reviewing the potential questions, she identified several concepts that her students had struggled with in the past. She noted that students had particular difficulties with bonding, isotopes, and realizing "it's all about the protons" when identifying an element.

    Emerging from our discussion was the joint decision to combine several categories, both because they were related thematically and would be taught during the same unit, and also to create a greater diversity of questions for each pre/posttest. The topic *elements and atomic structure* was chosen for the trial run activity since it would coincide with topics covered early in the school year. The three topics selected for the investigation were then 1) Bonding, 2) Physical Changes, and 3) Chemical Changes. The concise one or two word labels for each topic are used, in part, for convenience. Bonding, for example, should not be taken to mean a comprehensive coverage of bonding. It includes questions primarily related to covalent bonding and only one question on ionic bonding. Two underlying considerations impacted the selection of final topics and questions. First, each topic had to have approximately ten validated questions

(that is, ten validated questions each for Bonding, Physical Changes, and Chemical Changes). Second, the range of concepts for each topic could not exceed an amount that would be impractical considering the finite limitations of each time-constrained wiki activity.

    Personal experience. Having taught chemistry full-time for 18 years (three years high school, 15 years community college) I also brought to bear my own experience. A small percentage of the pre/posttest questions were adapted from my old exams and personal experience. It is important to point out that I don't recall the original source of these questions. That is, when I first used one on an exam, it is possible I had copied or adapted the question from a textbook or from the internet. Inserting one of my own questions was done when the diversity of validated questions from the literature fell short or I simply wanted to increase the degree of difficulty on the test to increase the likelihood of score variance.

    We will now turn to details of each of the three pre/posttests, with specific details about each question, rationale for the distractors (for multiple choice questions), and details about validation measures for questions taken or adapted from the literature. Unless otherwise stated, the value of each question was one point. The trial run pre/posttest will not be discussed here, but the test itself can be found in Appendix A along with the relevant references.

    Pre/Posttest #1: Bonding. See Appendix B for the Bonding pre/posttest.

    Question 1. This question, as well as several others, was taken from the National Science Foundation supported Facets project (SRI International, 2012). The intent of Facets, in part, is to elicit students' alternative conceptions through validated test

questions. Questions are aligned with national standards. The questions were retrieved from their Diagnoser tool, an online formative assessment platform (FACET Innovations, 2012). The validation procedures for this, and all Facet questions, involved pilot testing multiple times with over 100 students, review by high school chemistry teachers and other content specialists, think alouds with small groups of students, and revisions as necessary based on feedback. Distractors are often designed to elicit student misconceptions (Haydel Debarger, Ayala, Minstrell, Kraus, & Stanford, 2009; Minstrell, 2012). For this particular question, the misconceptions are (copied verbatim, as are all Facet misconceptions mentioned in this paper), choice (a) the student thinks that the number of electrons identifies the atom or that the number of protons and electrons identifies the atom; choice (c) the student thinks that the total number of nuclear particles (protons and neutrons) identifies the atom; and choice (e) the student thinks that all atoms of the same element have to have exactly the same number of protons, neutrons and electrons. I added choice (d) as another distractor. It was chosen because students might have the misconception that the number of neutrons identifies a particular element. Choice (b) is the correct answer.

Question 2. This questions is also from Facets (FACET Innovations, 2012). Misconceptions addressed are choice (a) the student confuses covalent and ionic bonds with each other (this explanation is directly from the Facets website but I don't see how it necessarily applies to choice (a)) and choice (b) the student predicts that a large difference in electronegativity between two elements will result in a covalent bond or that a small difference will result in an ionic bond. I added choice (d) as another distractor, and choice (c) is the correct answer.

Question 3. This question came from an old exam of mine (as stated above, I cannot be certain of the original source). Possible misconceptions for distractors are choice (a) student believes hydrogen has higher electronegativity; choice (c) the student thinks a bond between nonmetals always involves equal sharing of electrons; other researchers have noted this possibility (Özmen et al., 2009; Uzuntiryaki, 2003); and choice (d) the student reasonably believes *double* covalent bond represents *two* electrons shared. Choice (e) is a distractor and choice (b) is the correct answer.

Question 4. This question also came from an old exam. Possible misconceptions for distractors are choice (a) student believes a nonpolar bond will be between different atoms, and for the second part, "opposite" doesn't have a practical meaning in this scenario; choice (b) student believes electronegativity values need to be different for a bond to be nonpolar; choice (c) student believes a nonpolar bond will be between different atoms; and choice (d), student doesn't realize that nonpolar bonds form between atoms that are identical (identical in the electronegativity sense, which almost always means identical in every respect), not just *similar.* Choice (e) is the correct answer.

Question 5. This question too is from one of my old exams. Choice (d) is the correct answer because it represents the highest difference in electronegativities for the elements in the bond. Choices (a), (b), and (c) are incorrect but plausible in that students may believe the higher the sum of the electronegativities, the more polar the bond. For choice (e), students may believe identical elements bonded together yield the highest polarity.

Question 6. This question is from Facets (FACET Innovations, 2012). Misconceptions addressed are choice (a) the student believes that a "bond" between

atoms is a physical entity; choice (b) the student believes atoms have 'minds' and/or 'desires' and/or 'needs' (e.g. anthropomorphizing what determines how atoms bond); and choice (d) the student thinks that all electrons are involved in bonding rather than only valence electrons. Choice (c) is the correct answer.

Question 7. For this and other two-tier questions, students received half-point credit for a correct answer to each part of the question. This question is taken from the Chemical Bonding Achievement Test (CBAT) developed for a study discussed previously (Özmen et al., 2009). The CBAT questions, either taken from the literature or developed by the researchers, had content validity established by review of multiple individuals described as "chemistry educators" and "experienced chemistry teachers". Although the CBAT had 18 questions related to bonding, I chose to use only this question because the others dealt with bonding topics such as shapes of molecules, intermolecular forces, and polarity of molecules. Although these topics are part of the Metro High chemistry curriculum, they were not covered until after the end of the study. Choice (c) is the correct answer, paired with choice (1) in the first tier. Choices (a) and (b) reflect student misconceptions. For choice (a), in the Ozmen et al. (2009) study, almost one-third of the subjects thought, prior to the intervention, non-bonding electron pairs influence the position of the shared pair and determine bond polarity. For choice (b), slightly more than 1/3 of the students believed all covalent bonds involved equal sharing. No explicit reason was evident for including choice (d). It is reasonable to speculate that some students might believe that atomic size is related to its attraction for shared electrons.

Question 8. This question was taken from the Chemical Bonding Concept Test

(CBCT) (Uzuntiryaki, 2003). The authors were interested in comparing constructivist oriented teaching to more traditional chemistry instruction among ninth grade chemistry students in Turkey. Questions for the CBCT were developed through several routes. These included review of chemistry textbooks and the literature (concentrating on students' alternative conceptions), course objectives, and pilot interviews with teachers. Examination of the questions by a "group of experts in science education", and by the course instructor, was described as the means of establishing content validity (2003, p. 47). Choice (a) is the correct answer, paired with choice (1). For choice (b), the student presumably confuses characteristics of ionic and covalent bonding. Choices (c) and (d) have unknown alternative conceptions. For choice (d), if the student incorrectly also selected choice (2) for the first tier, the student might believe any compound with chlorine is ionic because it is so often used as an example of an ion.

Question 9. This question is also from the CBCT (Uzuntiryaki, 2003). Choice (b) is the correct answer, paired with choice (1). A possible misconception for choice (a) is that a student believes equal sharing of electrons occurs in all covalent bonds. For choice (c), students may think nonbonding electrons impact the position of the shared pairs (Özmen et al., 2009). For choice (d), a student may believe the polarity of the bond depends on the number of valence electrons for each atom in the bond. Choice (e) was added as an additional distractor.

Question 10. This represents the third CBCT question from Uzuntiryaki (2003). Choice (b) is the correct answer, paired with choice (2). For choice (a), a possible alternative conception is the student believes that metals and nonmetals from strong covalent bonds. The author lists this as an alternative conception of bonding, but doesn't

explicitly attribute it to this choice. For choices (c) and (d), the student likely doesn't understand the electronegativity of chlorine would be much higher than calcium. Choice (e) was added as another distractor.

Pre/Posttest #2: Physical Changes. See Appendix C for the Physical Changes pre/posttest.

Question 1. This is another question from Facets and is paired with question 2, from the same source (FACET Innovations, 2012). The correct answer is choice (c). I added choice (d) as another distractor.

Question 2. Choice (a) (question 1) with (a) (question 2), (b) with (a), or (c) with (a) suggests the student believes when a substance is used or burned, atoms are destroyed, disappear or are turned into a form of energy. Choice (a), (b), or (c) with (b) indicates a student believes when a new substance is created, atoms are created. Choice (a) or (b) with (c) is an unknown alternative conception. Choice (c) is the correct answer.

Question 3. This question is from a study by Mulford and Robinson (2002). They investigated students' alternative conceptions in first year college General Chemistry. Instrument creation involved first developing the questions either by writing them themselves (based on the literature) or taking them directly from the literature. Included in this process was a review of chemistry textbooks, journals, and American Chemical Society examinations. The resultant questions were pilot tested with an open-ended format and, after revisions, the final version was taken by graduate students to further check for clarity and length. Content validity was confirmed by "four experienced chemical education researchers". Choice (d) is the correct answer. In their study, only 40% of students (pretest) and 47% of students (posttest) identified this as the

correct choice. The most common alternative conception was that the bubbles contained hydrogen and oxygen gas (choice (b)). This belief was held by 43% (pretest) and 39% (posttest).

Question 4. This question is also from Mulford and Robinson (2002) and paired with the next question. The correct choice is (c). The researchers note that slightly more than one-quarter of the students (pretest) and slightly less than one-quarter (posttest) indicated the mass would be less than 27.0 grams.

Question 5. The correct choice is (b). The most prevalent incorrect reasons selected were "a gas weighs less than a solid" or "iodine gas is less dense than solid iodine" (Mulford & Robinson, 2002). The latter of these two is indeed correct as a standalone statement. It is not, however, the explanation for what occurs in this case.

Question 6. This is a Facets question (FACET Innovations, 2012). Alternative conceptions addressed are choice (a) student believes that atoms of the same element in different phases or compounds are actually different from each other and choices (b) and (d) the student thinks that the physical properties of a substance (color, density, hardness, etc...) are also properties of the individual atoms that make up that substance. Choice (c) is the correct answer.

Question 7. This is the first question from a chemistry concept test developed to explore the conceptual understanding of college General Chemistry students (Cloonan & Hutchinson, 2011). Extensive measures were taken to validate the instrument. A Ph.D. student in chemical education and two university professors reviewed the content and provided feedback. Additional input was provided by high school science teachers and well educated individuals from non-science fields. In the case of the latter, these

individuals did poorly on the test, thus providing evidence the test served the purpose of discriminating between low and high chemistry conceptual knowledge. That is, these highly educated non-scientists demonstrated that even bright people couldn't make an educated guess at the correct answer if they didn't know the content. In their paper, Cloonan and Hutchinson (2011) do not directly address the question I used. However, they do discuss the same alternative conceptions generally mentioned in other studies (Mulford & Robinson, 2002; Othman, Treagust, & Chandrasegaran, 2008). The correct choice is (b), which correctly demonstrates the sequence solid → liquid → liquid-gas mixture → gas.

Question 8. This question was taken from an instrument developed as part of an investigation into students understanding of the particulate nature of matter and chemical bonding (Othman et al., 2008). The tool was created by reviewing the literature and based primarily on the work of two other studies (Mulford & Robinson, 2002; Tan & Treagust, 1999). The correct answer is choice (5) with choice (d). The primary misconception being addressed was that water decomposes into hydrogen and oxygen when it evaporates. One-half point was awarded for a correct response to each tier of the question.

Question 9. This question is the first adapted from a longitudinal study investigating how students' understanding of chemical ideas changed from the beginning to the end of their chemistry course (Barker, 1995). This particular question was described as being modified from the literature. Feedback from science educators and pilot studies in a diversity of schools was used as the validation technique. In the study, this question contained a part not included here (in that case, students were asked to

describe what was in the container they hadn't chosen). The correct answers are D (a mixture of two elements), B (a compound), and A (one element alone). Two-thirds of a point was awarded for each correct answer. Thus, this is the only question on this test worth 2 points. No partial credit was awarded. For example, if for "a mixture of two elements" a student selected D *and* B, it was considered entirely incorrect.

   Pre/Posttest #3: Chemical Changes. See Appendix D for the Chemical Changes pre/posttest.

   Question 1. This question also came from Barker (1995). Regarding choice (a), a handful of students (11.0%) identifying a decrease in mass perhaps understood the underlying principal that mass is conserved, but incorrectly thought that a gas was released in the reaction, thus causing the mass decrease. For those who selected choice (c), they may have felt the final mass would be greater under the alternative conception that solids weigh more than liquids (13.3% of the students believed this). Choice (d) was added as a distractor and choice (b) is the correct answer.

   Question 2. This question is drawn from interviews designed to elicit understandings and alternative conceptions of precipitation reactions among General Chemistry students (Kelly, Barrera, & Mohamed, 2009). I developed the question in whole based on the results of the study, as I did the other questions derived from this research (questions 5 and 6 below). Choice (a) is the correct answer. Regarding choice (b), 2/3 of the students possessed the alternative conception that in precipitation reactions, both pairs of reactant ions change partners. For choice (c), there is no particular misconception identified with this choice, other than the student perhaps misunderstands the term "soluble". A handful of students had the alternative conception that the symbol

(aq) means a substance has changed into its liquid state, perhaps explaining why they would choose choice (d). Choice (e) is an additional distractor.

Question 3. This question also came from Facets (FACET Innovations, 2012). Misconceptions addressed were for choice (a) when a new substance is created, atoms are created; choice (b) when a substance is used or burned, atoms are destroyed, disappear or are turned into a form of energy; choice (d) the student believes that atoms are created (or destroyed) through ordinary daily events; and for choice (e) the student thinks that not all matter is made up of atoms. Choice (c) is the correct answer.

Question 4. This is another question adapted from Barker (1995). I altered it slightly to clarify that the water evaporated and then condensed. She found slightly more than 20% of the students did not conserve mass in their answers and gave varied explanations. The most prevalent was that a gas-liquid mixture weighs less than a solid. For those who chose choice (a), perhaps students possessed the alternative conceptions that mass increases on dissolving or because energy is absorbed. I don't expect many students to select this choice in the current study, however (Barker found less than 1% did). Regarding choice (c), students may possess the alternative conception that mass will be less than 400 g because a solid weights more than a gas/liquid (7.5% of Barker's students believed this) or that mass decreases because the phosphorus smoke dissolves (3.8%). I added choice (d) as another distractor, and choice (b) is the correct answer.

Question 5. The next two questions are based on the Kelly et al. (2009) precipitation study. Over half of the students had the misconception that aqueous ionic reactants were molecular pairs prior to being mixed. In other words, they did not believe the dissolved ionic solute in each solution existed as independent ions prior to one

aqueous solution being mixed with another. For question 5, choice (a) directly addresses this misconception. Choice (b) also addresses the misconception but in a manner that makes it appear the NaCl settles on the bottom as molecular pairs. Choice (c) is a plausible distractor because it *would* be the correct answer if NaCl were solid and not dissolved, and choice (d) is the correct answer.

Question 6. This question is based on two alternative conceptions. Kelly et al. (2009) found that many students believed that precipitates exist as molecular pairs and not three-dimensional lattices. The researchers also determined that many students felt aqueous "products" of precipitation reactions are molecular pairs and not free ions. Choice (a) is incorrect because everything is represented as a free ion, including the precipitate. Although it does not directly address the aforementioned student misconceptions, it is a reasonable distractor. For choice (b), the precipitate is correctly represented, but the aqueous "product" is shown as a molecular pair instead of free ions, thus addressing one of the alternative conceptions. Choice (c) is the correct answer, and choice (d) is incorrect because both precipitate and aqueous ions are shown as molecular pairs, thus addressing both of the alternative conceptions.

Question 7. The final three questions were added based on my personal experience. For question 7, in choice (a), students likely do not understand the substance which forms the solid is known as the precipitate. For choice (b), students perhaps possess the plausible alternative conception that the (s) designation stands for "soluble". For choice (c), students might contend that the spectator ions are those that form the precipitate. Choice (d) is the correct answer. In choice (e), the student likely believes that only cations are identified as spectator ions.

Question 8. This is paired with the previous question. Varied partial credit was given for partially correct answers. See Appendix E for details. A less detailed grading scheme was prepared before the study and adequately served as a rubric for the pretest results. The wide range of student answers on the posttest, however, necessitated a more thorough scale. The pretest was then regraded with the new scale.

Question 9. This question is very similar to questions found in many General Chemistry textbooks. See Appendix F for an explanation of partial credit. This is the only question on this test worth two points. As with the previous question, the rubric was revised after the posttest.

Reliability for pre/posttest. Coefficient alpha is "by far the most commonly used reliability coefficient" (Peterson, 1994, p. 382). It measures the internal consistency of a scale or exam. By contrast, reliability coefficients based on longitudinal data evaluate test-retest reliability (1994). Nunnally's recommended reliability levels are the most widely cited (1994). They are 0.5 – 0.6 for preliminary research (1967 recommendation), 0.7 for preliminary research (1978 recommendation; updated from 1967 without explanation), 0.8 for basic research, and 0.9 – 0.95 for applied research (1994, p. 382). The literature questions taken verbatim or adapted for this study generally met the preliminary or basic research thresholds. A representative example is the Chemical Bonding Achievement Test (CBAT), from which I used one question. Coefficient alpha was reported as 0.70 (Özmen et al., 2009).

However, for three reasons, this does not guarantee my instrument will exhibit a similarly acceptable degree of internal consistency. First, coefficient alpha reflects a sample of *scores.* "It is particularly important to recognize that scores, not tests, are

reliable or unreliable" (Vacha-Haase, Ness, Nilsson, & Reetz, 1999, p. 336). Thus, a second administration of the complete CBAT might have provided a different reliability coefficient. Second, numerous questions on my pre/posttest were used or adapted from research with international students (Barker, 1995; Othman et al., 2008; Özmen et al., 2009; Uzuntiryaki, 2003). A coefficient alpha based on scores from students in England, Turkey, or Singapore, does not necessarily generalize to Latino high school students in urban America. A study dealing with HIV education prevention echoes these sentiments. Commenting on low coefficient alpha values obtained after administering protection motivation theory instruments to Chinese high school students, Li et al. suggests "future study is needed to develop culturally appropriate and psychometrically adequate measurement of [protection motivation theory] constructs in China and other non-Western cultural settings" (Li, Zhang, Mao, Zhao, & Stanton, 2011, p. 420).

Third, and most importantly, each of my three pre/posttests is a collection of items from different sources. Therefore, if I use only one question from an 18 question assessment from the literature, the way that one question "hangs together" with the other questions on my pre/posttest will not necessarily be the same as the way it did with the 17 other questions on the original instrument. It is expected it will to a certain degree, since each pre/posttest is arranged by theme (Bonding, Physical Changes, or Chemical Changes). However, even within these categories, multiple concepts are assessed. For example, on the Bonding pre/posttest, a student who understands the nature of covalent bonding does not necessarily understand related ionic bonding concepts. Plankis (2009), who assessed knowledge of ocean literacy principles, found the coefficient alpha for his instrument was poor, 0.28. He writes that his self-created assessment is "not intended to

be a scale, it is simply a collection of knowledge items, so the low reliability coefficient is not a cause for concern" (p. 78). In many respects, my pre/posttests are also "a collection of knowledge items". For the chemical changes pre/posttest, for example, the topics range from conservation of mass in precipitation reactions, to solubility rules, to molecular representations of aqueous and insoluble ionic substances. In other words, unlike a protection motivation scale, or a self-efficacy scale, it is not expected the items on the three pre/posttests in the current study will "hang together" quite so well. A lower than ideal coefficient alpha, then, was expected and should not cause concern.

Peterson (1994) notes that "a scale in the preliminary stages of development is generally not thought to require the reliability of one used to discriminate between groups or of one being used to make decisions about individuals" (p. 381). Two points of emphasis are necessary based on this comment. The first is that I *am* discriminating between groups and thus perhaps I do need to exercise caution about excessively low coefficient alphas. Second, however, I am not developing a scale in the spirit of Peterson's comment. Further, my research is preliminary in the sense there were no available instruments I could have used for the current study, and, to my knowledge, no other studies of any kind that have analyzed how Latino adolescents learn chemistry using a wiki. Thus, with all this about reliability in mind, as well as Whitson's (2009) comment that "coefficient alphas are usually low and conservative estimates of reliability" (p. 49), the minimum acceptable coefficient alpha for the current study will be set at 0.50.

Subjects

Metro High School is a public charter school serving grades 9-12 in a major

Midwestern city (citations withheld to protect anonymity). The school has an explicitly

stated college preparatory orientation and requires four-years of college prep English,

Math, Science, and History/Social Studies. Enrollment is several hundred and is over

95% Latino. After-school programs are available on most days where students are

encouraged to seek additional academic assistance. Attendance at these sessions is

mandatory for students who are in danger of failing.

Results on standardized state tests indicate a favorable comparison to other

schools within the district. Although students who scored at the Grade 10 Advanced or

Proficient level in Reading, for the current school year, were slightly less than district

averages (11.7% vs. 13.8%), in both Grade 10 Language Arts and Science, their scores

were considerably higher (70.1% vs. 39.6%, and 56.9% vs. 36.7%, respectively). The

percentage of students scoring at the minimum performance level in Reading was

favorable compared to the district average, but still almost 30%. Compared to statewide

students, Metro High had lower percentages of Grade 10 students at the Advanced or

Proficient level for Reading (11.7% vs. 38.45%) and Science (56.9% vs. 75.5%), but

almost the same percentage for Language Arts (70.1% vs. 72.9%) (Wisconsin

Information Network for Successful Schools, n.d.).

The subjects in the current study were 48, mostly third year, college prep level

chemistry students. The students were distributed over three sections of the same course,

all taught by Jody. Prior to taking the course, most had two years of science: Physical

Science and Biology. Jody, a white female, was in her second year of teaching at Metro

High, and overall. Slightly more than a year removed from receiving a dual Bachelor's

in Chemistry and Environmental Science, she was pursuing her Master's degree in

Education during the period of the study, taking two graduate classes per semester.

Institutional Review Board (IRB)

The study was granted exempt status by the Marquette University Institutional Review Board under the category "Normal Educational Practices and Settings". See Appendices G – K for IRB documentation.

Experimental Design

General design characteristics. The study is a quasi-experimental pre/post control group mixed-methods design. It used three intact sections of a high school chemistry course, all taught by the same teacher. This eliminates the concern that teacher differences might influence outcomes (Hilton & Nichols, 2011). Every effort was made to have identical instruction in both treatment and control groups, save the experimental conditions. To that end, before each activity, the teacher was provided with mutually agreed upon general guidelines (a "Cheat Sheet", as we referred to it). Among other things, the guidelines outlined what to cover on the activity introduction day, when to provide feedback on the wiki discussion forum, and what to cover in the control classrooms. Thus, in these regards, there were controls in the study, mostly based on what was learned from the literature about wiki activity design. See Teacher "Cheat Sheets" in Appendices L - M for complete details. Note that from this point on, the treatment group will be referred to as the wiki group and the control group will be designated the normal instruction (NI) group.

Many aspects of the design are naturalistic, however. For this reason, the study could also be described as *quasi-natural*, as Bruner's early scaffolding interactions were.

Stone (1998) suggests these "quasi-natural" events were such that "no explicit attempt was made to manipulate the nature of the tasks, or to specify or constrain the nature of the interaction" (p. 346). The spirit of those comments is reflected in this study. The verbal feedback the teacher provided during small group sessions, or during after school one-on-one help, or in written email feedback, or most interactions with students, was not constrained in any way. Face-to-face and virtual communication among peers was completely naturalistic.

Threats to validity. The naturalistic aspects of the study help reduce threats to external validity (Patten, 2012). However, quasi-experimental designs are generally subject to multiple threats to internal validity. These include *mortality* (greater loss of participants from one group than another), *history* (one group being exposed to certain environmental conditions more so during the treatment than the other group), and others (Patten, 2012). However, a design feature of this study specifically guards against this. The wiki and NI conditions were rotated such that each class served as the wiki group once and NI group twice (see Table 2). This should greatly minimize any internal threats that generally result from nonrandom assignments. Further, the internal threat of *testing* (students performing better on the posttest as a result of remembering content from the pretest) was minimized by administering the pretest for all three activities during the first week of school, well before the administration of each respective posttest.

Determination of sample size. A brief discussion of the statistical concept of power is worthwhile to explain how sample size was determined. Cohen (1992) defines power as "the statistical power of a significance test is the long-term probability, given the population ES, alpha, and N of rejecting H_o". Power can also be thought of as the

Table 2

Wiki and Normal Instruction Assignments

	First Hour Class	Fourth Hour Class	Sixth Hour Class
Bonding (November)	Wiki (n = 17)	NI (n = 16)	NI (n = 15)
Physical Changes (December)	NI (n = 17)	Wiki (n = 16)	NI (n = 15)
Chemical Changes (February)	NI (n = 15)	NI (n = 16)	Wiki (n = 14)

probability that you will not make a Type II error, β. Stated another way, Power = 1 – β (Faul, Erdfelder, & Lang, 2007).

The power of a study can be manipulated in five ways. First, one can raise the alpha level from say, .05 to .10. The drawback of this, however, is doing so raises the possibility of a Type I error (rejecting the null when in fact we shouldn't because the research hypothesis is false) (Aron, Aron, & Coups, 2006). Thus, for my study the alpha level was kept at the traditional .05 level. A second way to increase power is to use a one-tailed, instead of two-tailed test (Aron et al., 2006). However, the exploratory nature of my study dictates the analysis should be two-tailed, since I don't have any firm basis to assert that a wiki activity will necessarily improve scores. A third method of increasing power is to have smaller standard deviations for the two groups, treatment and control. This can be accomplished by using less diverse groups of students (diversity in terms of ability to perform well on the pre/post assessments) (Aron et al., 2006). However, with intact groups this isn't possible and not even desirable for a study trying to maintain as natural a setting as possible within the realm of a quasi-experiment.

A fourth way of increasing power is to increase effect size by essentially using a more intense intervention so the difference in means between treatment and control is greater (Aron et al., 2006). In this study, that might amount to increasing the time on task for the wiki (say, have the students work on it for eight weeks instead of four). This, however, wasn't practical as it would devote too much time to certain aspects of the course objectives at the expense of others. Finally, the fifth way to increase power is to raise sample size. Raising the sample size reduces the standard error of the mean (Aron et al., 2006). To a certain degree, this can be controlled in the study. While the classes are intact, and enrollment cannot be altered, the treatment can be employed multiple times and the data of each intervention used collectively to, in effect, raise sample size. In the end, this is what was done.

Before performing the *a priori* power analysis to determine sample size, I needed an expected effect size. To estimate effect size, it is recommended to use sample means and variances from related studies (class notes). In my case, I used the three most comparable studies in the literature discussed earlier, all quasi-experimental pre/post control group designs in high school chemistry, albeit international "high schools" in two cases (Çentıngül & Geban, 2011; Hand et al., 2007; Özmen et al., 2009). Taking into account the sample size of each of these three studies, the weighted average effect size was .95.

A priori power analysis was performed with the statistical program G*Power (Faul et al., 2007). Cohen (1992) recommends a compromise power level of .80. Anything less would invoke too great a risk of a Type II error. Anything more would likely require too great a sample size. Therefore, taking into account a power of .80,

estimated effect size of .95, alpha of .05, a power analysis for a two-tailed t-test for independent means suggested the sample size should be 38 (19 wiki, 19 NI). Since class sizes are expected to be roughly 15 students per class, this fell a bit short of the required 19 per group (although it would have provided enough students overall, 45).

Therefore, to increase sample size and maintain the power of at least .80, three interventions will be implemented, each time rotating the groups as shown in Table 2. With 17, 16, and 15 students per section respectively at the start of the school year, a pooled sample size from three interventions would yield 48 wiki students (17 + 16 + 15) and 96 NI students ([17 + 16 + 15] x 2). This well exceeds the 19 per group suggested from the power analysis, but for four reasons I preferred the excess.

The first, and perhaps most important, is I am going to presume the very high effect size of 1.73 from the Çentıngül & Geban (2011) study is somewhat anomalous. Therefore, if we only use the more conservative estimates of the other two studies, .61 and .59, the average effect size is .60. This is more in line with what is typical for educational interventions, which generally have an effect size well below one (Aron et al., 2006, p. 197). Redoing the power analysis with an estimated effect size of .60, and keeping power level at .80 and alpha at .05, our required sample size is then 90 (45 in each group), coincidentally matching very closely my proposed scheme. A second reason for doing multiple interventions is that it gives each class an opportunity to participate fully. Third, the additional interventions will produce more qualitative data, something that will generate more informed conclusions for the second research question. The fourth and final benefit of multiple interventions, with concomitant group rotation, is it reduces threats to internal validity, as described above.

Pre-activity briefing. Before the first activity, Jody and I had a fidelity of implementation meeting. Similar pre-intervention briefings are described in the literature (Çentıngül & Geban, 2011; Özmen et al., 2009). We discussed in detail every aspect of the activity. Once procedures were finalized, all being mutually agreed upon, a "Cheat Sheet" friendly reminder was sent to Jody, by email, shortly before each activity.

Trial run. A trial run wiki activity took place at the start of the school year. All three sections participated. The purpose was to get students familiar with Wikispaces (Tangient LLC, 2013), the wiki platform used for the study. In addition, it was to get accustomed to collaborating with group members (group membership was later retained for the next wiki activity, that which was part of the study), and to the general expectations that would also be retained in the next activity. The trial run theme was Elements and Atomic Structure. Before the multi-week activity began, I gave a 25-minute presentation to students on using Wikispaces. This marked the only teaching I did for the entire study. My presentation included explanations on topics such as how to login, adding text, adding images, adding hyperlinks, retrieving or reviewing prior versions of a page, creating tables, embedding videos, and posting to the discussion board. Help pages on all these topics were also developed and added to the student wikis so they could access them at any time (see Appendix N for a sample Help page). Although students took a pre/posttest based on this trial run content, it was not included in the data analysis.

Pretest. During the first week of school, students took the combined pretest. It covered the trial run topic of Elements and Atomic Structure, and the three study topics of Bonding, Physical Changes, and Chemical Changes. As noted earlier, this put

considerable time between the pre- and posttest (from two to six months, depending on the activity) and helped minimize the internal threat of testing. The equivalence of wiki and NI groups before the interventions was established by performing a t-test for independent means on the pretest results. Statistical analysis of pretest scores for such a purpose, t-test or otherwise, has been done in related studies, some of which were described above (Basili, 1988; Çentıngül & Geban, 2011; Hand et al., 2007; Hilton & Nichols, 2011; Özmen et al., 2009).

Concurrent instruction. During each of the three wiki activities, both the wiki and NI groups received their "usual" instruction, save the treatment and control conditions related to the study. Such attempts at consistency have been described before (Basili, 1988). This included having the same regularly assigned homework problems, class notes, in-class practice problems, and exams. Embedding the wiki activity as just one part of "normal" instruction, rather than as a "one-shot" standalone activity, is based in part on evidence that an intervention *plus* an expert lecture leads to optimal learning, including strong transfer (Bransford & Schwartz, 1999).

Wiki templates. Each wiki activity (Bonding, Physical Changes, Chemical Changes) had four topics, each being on a separate page of a particular group's wiki. Although the general expectations varied slightly for each topic, there was one consistent theme. That is, whether dealing with spectator ions, electronegativity, conservation of mass, or any of the other topics, students were asked to *creatively* explain the chemical concept to someone who had a limited chemistry background, such as a family member, or a friend who had never had a chemistry course. The idea behind this was that students would be compelled to communicate the often abstract concept in a more straightforward

manner, using "clear, simple language" (Stout, 1997). As described above in the study in which high school chemistry students wrote letters explaining stoichiometry to seventh graders (Hand et al., 2007), it was hoped the exercise would promote deep thought. Suggestions for creativity were provided, such as an analogy, poem, or creative video. However, there were no restrictions on what form the creativity could take. The primary point was to give students, by encouraging their creativity, the opportunity to draw upon their funds of knowledge (Gonzalez et al., 1995). See Appendices P – R for screen shots of the wiki templates for each topic (written permission to use screen shots of Wikispaces was obtained from their corporate office).

A minor difference between the Physical Changes template and the Bonding and Chemical Changes template was the former had an extra link in the right menu bar titled "Resources Page". The link led to a wiki page composed of two links (each going to molecular level animations of phase changes) and one embedded video about the difference between compounds and mixtures (see "Mixtures and Compounds," n.d.; "States of Matter," n.d.; "Sublimation," n.d.). These were placed here, rather than on the pages for Topics 1 – 4, to avoid excessive preloaded content on the topic pages themselves. Students in the Physical Changes activity were advised they were welcome to access the Resources Page as they might any other web page. They were not, however, required to do so. The rubric was altered such that they could not rely solely on this page for the requirement to have an image, embedded video, or link. That is, like the Bonding and CC groups, they had to find at least one other such resource from an external source.

Rubric. See Appendices S - U for the rubrics for each of the three activities. The

first week or so of each wiki activity was intended to be primarily individual work. During this initial phase, each group member had a deadline for making their initial contribution. This was generally set within a few days of the activity start. Several days after that, each group member had another deadline. That is, completing a first draft of the topic initially assigned to them. These deadlines were imposed because, generally speaking, proximal goals are more likely to be met than distal ones, as described earlier. Over a range of content areas, the literature suggested checkpoints were established in wiki projects for a variety of tasks (Evans & Moore, 2011; L. Lee, 2010; Matthew et al., 2009). Thus, that lead was followed in the current study. For their first draft, the rubric generally specified students would receive credit for clear and accurate explanations, creativity, and inclusion of an image, video, or link, accompanied by an explanation.

For the second half of the activity, lasting roughly one week (see Appendix BB for timetables), the project was intended to be collaborative. Generally, each group member was required to make at least one significant contribution to the wiki for each topic not initially assigned to them. The rubric clarified this could be done by adding significant text, an image, video, or link, with explanation, or by adding an additional example, also with explanation. This requirement to edit what someone else initially contributed was, in part, an extrinsic form of incentive to help students overcome the general hesitancy of editing another's work. This dilemma was described in the literature review (Lazda-Cazers, 2010; L. Lee, 2010; Matthew et al., 2009).

Before the activity midpoint, scores earned by students reflected only individual contributions. The quality of the final product, however, was evaluated as a group score, each member receiving the same score regardless of the extent of their contribution. The

group score for one of the Bonding topics provides a representative example. Points were awarded, to all members of the group equally, if the chemistry concepts were explained clearly and accurately. Additional points were earned if students addressed criteria specific to the topic, such as including a description of electronegativity in their own words, in this case. Credit was also awarded for including an image, video, or link, along with an explanation. Finally, creativity was factored in.

Three additional incentives were provided to encourage maximum participation. First, students were told they could replace their activity score from the trial run if they scored higher on their second wiki activity (for each of the three chemistry sections, their *second* wiki activity was part of the study). Second, to encourage usage of the discussion forum (which was underutilized during the trial run), extra credit was possible for those who posted a message on the forum or who replied to a posting by a fellow group member. Finally, extra credit was also offered for developing a multimedia presentation that could be included on their wiki. Students could select any form of presentation they wished. Suggestions included Animoto, GoAnimate, and Prezi, all free, web-based platforms (Animoto Inc., 2013; Prezi, 2013; Tangient LLC, 2013). The scores students received based on the rubric were not incorporated into the current study. They did, however, impact their grade in the course.

Wiki implementation. This section will describe the wiki activity itself. See the teacher "Cheat Sheets" in Appendices L – M for additional details. See Appendix BB for a timetable of events for each activity.

Introduction day. Each of the three activities opened with students receiving a roughly 30-minute, whole-class introduction. Jody began by describing what we learned

from the trial run, such as students appearing to enjoy using the technology and the opportunity to be creative. At the same time, many were hesitant to collaborate by editing someone else's work. The informal trial run feedback also suggested a preference for face-to-face over online communication. For the benefit of the students, Jody acknowledged working collaboratively was difficult, especially with an unfamiliar technology, and encouraged the students to give it another try. She highlighted how this type of activity was important for developing 21st century skills, a point that reinforced for students what they had heard before at school assemblies. Jody discussed some specific benefits of collaborative work. These included group members being able to notice your mistakes, learning to treat other's opinions with respect, and how explaining your point of view promotes deeper understanding. It was made clear that feeling hesitant to edit someone else's work is quite common, but that it was important to try and overcome that.

The teacher also led a brief discussion about one of the four topics, just enough to get the students thinking about the expectations. She started with something like, "Let's brainstorm. What's a creative way to describe to someone that when atoms come together to form a bond, they release energy and become more stable?" Time was limited, however, so only about 5-10 minutes was devoted to this. Another roughly 10 minutes was also spent going over the rubric. Jody highlighted that although the general expectations were the same as the trial run, there were some minor changes. Students were also reminded they were encouraged to communicate in Spanish if they wished, either on the wiki or face-to-face. The final version of their project, however, needed to be in English. With the aid of a projector, the teacher also reminded them where various

links were within the wiki. These included help pages and sample topics with idealized

answers. See Appendix V for the Sample Topics page.

For the final 8-10 minutes on the introduction day, students moved to the

computer lab. They were instructed to gather in their groups, around one or two

computers, with each student making sure they could login. They then were expected to

read their four topics and assign an initial topic, or two, to each group member (groups

ranged from three to five members, with the usual being four). Time permitting, they

were then asked to begin an initial discussion of how they might creatively address the

expectations for each particular topic.

Between introduction day and midpoint meeting. During this period, each group

member was expected to develop the wiki page for the topic initially assigned to them.

The expectation was that each group member would, at this point, *not* edit a topic other

than their own. In other words, development of each page was intended to be an

individual effort, at least initially. Communication between group members, or between

the teacher and the students, was in no way prohibited, however. The teacher was free to

scaffold the students during this interval, as time permitted. This could occur in any

manner that was convenient, including email, face-to-face, or by any other means.

Day before midpoint meeting. The morning of the midpoint (or, in the case of

the Bonding activity, the night before), detailed teacher scaffolding[11] was posted in the

---

[11] Unbeknownst to students, the teacher feedback they received in the discussion forum was originally composed by the researcher. I would compose the feedback, forward it to Jody, who then had the opportunity to review, edit, and post for students. This procedure reflected practical considerations, rather than experimental design. As noted earlier, during the study period, Jody was teaching full-time (in only her second year of teaching) as well as taking two graduate courses per semester. Rather than add any additional burdens, beyond those that participation in the study already had, we decided it would save her time if I created a first draft of the written feedback. It is important to emphasize she had complete discretion to edit anything I contributed.

discussion forum for each topic. The feedback was based on an evaluation of their first

draft. The posting was intended for the entire group, rather than the individual who

composed the draft. When possible, it was uploaded the day before the midpoint so, if

they were able, students could read it before meeting in the computer lab to discuss. In

addition, Jody was asked to provide several reminders to students via email or during

class. These dealt with the general expectations for the balance of the activity, with an

emphasis on how the second half was intended to be collaborative. In addition, students

were provided specific guidance on what to do during the midpoint meeting the following

day.

      Midpoint meeting. For the midpoint day, students met in small groups, in the

computer lab, to have face-to-face discussions about the progress of their wikis. They

were asked again to isolate themselves with group members in a part of the room where

they could gather around one or two computers. Groups then read and discussed all four

topics, including the posted feedback from the teacher, with the intended focus being on

how to act on the scaffolding in order to make improvements. Students were also

expected to perform a self-assessment of each topic. That is, to give themselves a score,

based on the final criteria as spelled out on the rubric. The point of this was to call their

attention to shortcomings that they still had an opportunity to rectify through

collaboration. An entire 45 minute class period was devoted to this midpoint meeting. It

marked the second and final time students formally met with group members.

      Between midpoint meeting and final due date. During this period, wiki

development was expected to be collaborative.   Jody was asked to provide feedback to

students as time permitted.

Several days before final due date. Detailed teacher scaffolding was again posted in the discussion forum. It was based on students' progress since the midpoint. The teacher was also asked to remind students, via email or in class, to read the discussion forum postings for all the topics in their wiki, not just the one for their initial topic. Specifically, Jody was asked to remind them that if they hadn't already done so, to make at least one significant contribution to each topic not initially assigned to them, and if they can't find something to improve on, to add an additional example, with explanation. Further, to let them know again that everyone in the group would get the same final score for each topic, so it's in everyone's best interest to review the rubric and make sure every topic is the best it can be. Occasionally, Jody would blind copy me on these emails to students. It is not known, however, the exact frequency with which these reminders occurred, both by email or face-to-face.

Day before final due date. Students reminded by email or in class that wikis were due at midnight the following day.

Final wikis due. Deadline for wiki completion was generally a day or two before the posttest, as it was before their unit exam. The unit exam was not part of the current study.

Control conditions. This applies to both the introduction day and the midpoint day, the two occasions in which the treatment group did not have ordinary classroom instruction. On these days, control students either did end-of-chapter problems, or read and summarized textbook content, both related to the same topics on the wikis. This is consistent with at least two studies in the literature. In the study involving writing a letter to seventh graders about stoichiometry topics, control group students wrote summaries of

textbook content, or did end-of-chapter problems. This occurred, of course, on the days

the treatment group wrote their letters (Hand et al., 2007). Another study also matched

time on task with the treatment group by having control students also do end-of-chapter

problems (Özmen et al., 2009).   See Appendix W for sample NI group problems.

     Posttest. The posttests were administered shortly before the end of the respective

units. Students were given half-point extra credit on the upcoming unit exam for each

correct answer on the posttest. This was done as incentive for full effort. Once graded

and returned, the results and feedback from the posttest could be used as a formative

assessment for all students, wiki and NI, to help them prepare for their unit exam.

Data Sources and Analysis Procedures

     Quantitative analysis. Using the collective data from the three interventions, a t-

test for independent means was computed to compare posttest scores from the wiki and

NI groups. The decision to use posttest scores for the comparison, rather than gain

scores, deserves some attention. The use of gain scores (also referred to as *difference*

scores) has been criticized by many. Some claim a gain score cannot have both high

reliability and high validity (Willett, 1988). They have been described as so unreliable

that "investigators who ask questions regarding gain scores would ordinarily be advised

to frame their questions in other ways" (1988, p. 345; quoting Cronback and Furby). On

the other hand, Willett (1988) suggests that "it has become apparent in recent years that

the difference score is not *necessarily* unreliable" (p. 368; emphasis in original). He

claims "authors in the empirical and methodological literatures have criticized the

difference score so thoroughly and continuously over the years that investigators have

become wary of its use in their research" (1988, p. 366).

Thus, because differences of opinion exist among experts, and even Willett qualifies his favorable opinion of gain scores by stating they are not *necessarily* unreliable, I assessed their potential use in the current study. In doing so, I have come to the conclusion, based on what I describe below, that although the pretest score is the best available measure for establishing initial equivalency among groups, it is not reliable to the degree it should be used in calculating gain scores. The gain scores then are expected to be unreliable since they are based, in part, on the pretest score. Consider for a moment that you have a pretest that evaluates a construct like self-efficacy. A question might be "I always feel confident about solving chemistry problems", and then subjects would need to select from a Likert scale such as 1 = not true at all, 2 = a little bit true, 3 = mostly true, 4 = exactly true. When a person takes this pretest, it's probably safe to assume two things. One, they basically understand what the question is asking, and two, they understand the meaning of the choices and will select one that reasonably matches their perceptions. The important point is, they are not just guessing.

A pretest question from the current study provides a counter example. Question 3 from the Bonding pretest (Appendix B) will serve as our example, although just about any question would suffice. A student who sees this question, and who is in his/her second day of chemistry class (as was the case in the current study), will very likely have *absolutely no idea* what this question is asking. This one question involves multiple concepts that very likely were never even touched on in previous coursework. Even if some of the concepts were covered, likely not nearly in the detail required to have a reasonable chance at getting the question correct with confidence. In other words, for almost all of the items on the pretest, most students are doing little more than guessing.

For this reason, for a test so heavily laden in unfamiliar content, there is no reason to believe the pretest, or the gain scores which incorporate pretest scores, would be reliable. Therefore, like other quasi-experimental studies involving adolescent chemistry students (Çentıngül & Geban, 2011; Hand et al., 2007; Özmen et al., 2009), pretest scores will be used solely to establish equivalency among groups. The posttest scores, then, will be used to compare groups.

Qualitative analysis.

Data sources. The small group discussions in the computer lab were audio recorded and transcribed. This included both the brief meeting on the introduction day, and the lengthier one on the midpoint day. For each activity, two groups (out of four) were selected to participate in focus groups. See Appendix X for focus group protocol. Purposive criterion sampling determined the groups to be selected. Purposive criterion sampling selects subjects which are not only rich sources of information but who also fit one or more specific criteria (Patten, 2012). In this study, groups were chosen such that a representative sample was obtained which included some strong wiki performers, some average wiki performers, and some poor wiki performers. This performance was based on their wiki activity rubric score.

A teacher interview was also conducted after each of the three activities. See Appendix Y for the teacher interview protocol. Both the focus groups and teacher interview were semi-structured in nature, as is common in qualitative research (Patten, 2012). Wiki content, discussion forum scaffolding, and field notes, were also analyzed. A brief student internet access survey was also taken into account. See Appendix Z for the survey.

Analysis. The qualitative analysis will be outlined here by first briefly describing relevant aspects of another scaffolding-focused dissertation. Within the context of a multi-age primary classroom, Gnadinger (2001) examined peer collaboration as a means of instruction. Data sources were strictly qualitative, including videotaped peer interactions, teacher reflections, student artifacts, and field notes. The underlying purpose of the investigation was to determine the nature of "joint productive activity" by examining student-student scaffolding (2001, p. 67). It was therefore similar to my second research question, which aims to elucidate the characteristics of distributed metacognitive scaffolding among Latino high school chemistry students. The best way to do this, as Gnadinger describes in her paper, is through a "structured but flexible" qualitative analysis (2001, p. 78; citing Mason).

Specifically, she began her analysis with pre-existing codes in mind. In her case, they were Tharp and Gallimore's six means of assisted instruction: questioning, modeling, cognitive structuring, contingency managing, instructing, and providing feedback (Gnadinger, 2001, p. 79). This pre-determined decision served her well. She identified many instances in which the observed peer interactions fit into one of the six categories. In her results, then, she included rich descriptions and examples that justified a particular coding. For *questioning* and *providing feedback*, for example, data from her field notes and student videotapes were coordinated to provide a revealing look at two boys working collaboratively to problem solve. From her field notes, she began "Shane and Austin are working on constructing their roller. The boys have placed pencils…" (2001, p. 141). After completing that description, she included an extended excerpt from their dialogue which illustrated both questioning and providing feedback. For example,

when Shane indicates he doesn't understand the task, Austin is able to provide the following feedback, "I mean look. We're making a roller, right? So this part here (pointing to the pencils) must be the part that rolls. Get it?" (2001, p. 142). The dialogue then continues for several more lines. This use of predetermined codes represents the "structured" aspect of her qualitative analysis.

However, after beginning her coding, it became evident to her that another category of scaffolding was needed, a *suggestion*. This represents the "flexible" aspect of her analysis. She found that while one peer might offer a suggestion, the other responds to it in one of three ways: rejecting it, ignoring it, or accepting it. She then proceeded to provide examples of each, in a manner similar to that described above for *questioning* and *providing feedback*. In applying a flexible approach, she tapped into an essential characteristic of qualitative analysis. That is, it is inductive. This is consistent with the grounded theory approach which often guides interpretative work (Patten, 2012). Finally, Gnadinger triangulated data from videos, artifacts, and teacher reflections to "strengthen validity and reliability"[12] of the study (Gnadinger, 2001, p. 81). An inductive, flexible approach and triangulation of data are widely accepted fundamentals of interpretive research (Lincoln & Guba, 1985).

The current study will employ a similar "structured but flexible" analytical methodology. The "structure" is shown in Table 3. That is, analysis of data sources will look for examples of metacognitive scaffolding that align with assistance in *recognizing knowledge gaps*, such as encouraging or aiding a student in reflecting on knowledge related to 1) content (MS-CK), 2) general goals (MS-GGK), and 3) making connections

---

[12] The terms *trustworthiness* and *dependability* are more commonly used in qualitative research as loose interpretations of the more quantitative terminology, validity and reliability (Patten, 2012).

(MS-MCK). Further, analysis will also seek to identify examples of metacognitive

scaffolding that support assisting in *knowing what to do* about knowledge gaps, such as

encouraging or aiding a student in reflecting on knowledge related to strategies (MS-SK).

Table 3

Analysis grid for metacognitive scaffolding

	Recognizing Knowledge Gaps			Knowing What to Do About It
	Content Knowledge (MS-CK)	General Goals Knowledge (MS-GGK)	Making Connections Knowledge (MS-MCK)	Strategy Knowledge (MS-SK)
Teacher				
Peer				

Interacting with this framework was each of the three primary components of

distributed scaffolding. That is, teacher, peer, and computer scaffolds. Thus, the

qualitative analysis amounted to filling in the blank cells in Table 3 with descriptions and

examples. Notice that computer scaffolds are not represented. After data analysis was

complete, it was determined that since computer scaffolds were far less common than

teacher or peer scaffolds, they would just be incorporated into the teacher or peer

categories as appropriate. In addition to these pre-determined categories, qualitative

analysis was also "flexible". Emergent categories were included as the data dictated.

As a further means of improving the trustworthiness of the conclusions,

Gnadinger (2001) describes how two colleagues checked her coding. The colleagues and

researcher discussed the rationale and feedback was provided. In a similar manner, an

experienced chemistry teacher, Dave Wilson, filled that role in the current study. Dave

has nine years of full-time experience teaching chemistry at the community college level.

Together we reviewed my coding for the distributed metacognitive scaffolding and

generally agreed on my assignments. However, where he made a point I hadn't

previously considered, it is explicitly mentioned in the Results chapter. Trustworthiness

of the data was established through data triangulation. That is, multiple sources of data

(face-to-face dialogue, wiki content, focus group comments, etc…) providing similar

information.

Chapter 4: Results

The Results chapter will begin with the first research question. Quantitative data will be described first. After that, qualitative results will be divided into two sections. The first section will cover complete sequences of selected groups. That is, we will follow the wiki activity experiences of small groups of students from start to finish. The second section will address data dealing with the general characteristics of scaffolding (intersubjectivity, calibrated assistance, fading), keeping an eye toward how this data can inform the quantitative results.

The second research question will then be addressed. Using the "structured yet flexible" approach described above, the four themes of distributed metacognitive scaffolding (MS-CK, MS-GGK, MS-MCK, MS-SK) will provide the "structured" framework. The "flexible" approach will facilitate a more nuanced interpretation by allowing for emergent categories.

Research Question 1

Research Question 1: Is there a difference in academic achievement between a treatment and control group on selected concepts from the topics of bonding, physical changes, and chemical changes, when Latino high school chemistry students collaborate on a quasi-natural wiki project?

Hypothesis 1: As measured by posttest scores, the academic achievement of the treatment group will be greater than that of the control group.

Quantitative results.

Pretest. A concern about response patterns arose after administration of the

pretest. For two-tiered questions (see Question 7 of the Bonding pre/posttest in Appendix B as one example), it was intended that students would circle (1) or (2) for the first tier *and* also circle a, b, c, or d for the second tier. Many students (23 out of 47) failed to circle their choice for the first tier. Considering the poor performance overall on the pretest, there is a chance they just didn't know the answer and skipped it. Since so many students were involved, however, it seems more likely they were uncertain of the expectations.

The overall impact of this is probably minimal for several reasons. First, this type of question represented only four pretest points for the Bonding activity, only one point for Physical Changes (PC), and zero points for Chemical Changes (CC), each out of a total of 10. If you consider that a student could still get a half-point on each question if they correctly circled only one tier, the maximum number of points missed by failing to understand the directions was only two points, 0.5 points, and zero points respectively. Second, the average pretest score was very low, 2.01 out of 10. Thus, even if students understood the directions fully, there is high probability they would have selected the wrong choice. Third, whatever impact this misunderstanding had on the wiki group would be balanced out by the normal instruction (NI) group.

However, one limitation of my interpretation is that evidence suggests the issue may not be evenly distributed between wiki and NI. For example, if we focus just on the Bonding pretest (the one test where this issue could possibly be a major source of error), five out of 17 wiki students (29.4%) failed to realize the correct answering procedure. In the NI group, however, considerably more students, 18 out of 31 (58%), made this error. Assuming that at least some of these additional NI students would have chosen the

correct response, the ultimate result is that NI group pretest scores might be disproportionately depressed. This would throw off the ability to use the pretest to establish equivalency of groups.

Thus, pretest scores were analyzed twice, once with no test items dropped and a second time with two-tiered items dropped. In the latter case, for example, the Bonding pretest had 10 questions originally. After discarding the four two-tiered questions, six questions remained, worth one point each. The new grade was then scaled to 10 points total to make it consistent with the two other pretests (recall that the wiki and NI groups are composed of collective scores from the three activities, each of the three classes doing the wiki activity in turn, while the other two receive NI). Independent samples t-tests were then used to determine if the wiki and NI groups were statistically equivalent in each case (i.e. with no items dropped and with two-tiered items dropped). In both instances the groups were determined to be statistically equivalent on the pretest (see Table 4). In other words, the pretest results were not impacted by the fact that some

Table 4

Mean Pretest Scores (Collective Scores from Three Activities)

	Wiki ($n = 47$)	Normal Instruction ($n = 94$)	t	p	df
No Items Dropped	1.88 (1.24)	2.07 (1.47)	.745	.458	139
Two-tiered Items Dropped	1.93 (1.48)	2.25 (1.70)	1.11	.268	139

Note: Standard deviations appear in parentheses below means.

students might have been uncertain of how to answer the two-tiered questions. Earlier in

the Methods chapter, the reliability of the pretest scores was called into question.

Nevertheless, for this study, it remained the best available option to establish equivalency

of groups before the intervention. It is worth noting that on the posttest there were no

misunderstandings of how to answer the two-tiered questions. The students were given

clear instructions on the answering procedures immediately beforehand. The teacher also

double checked student papers as they were turned in.

   Posttest.

   Reliability. Internal consistency (coefficient alpha) was evaluated for each

respective posttest. To prepare the data for reliability analysis, each single-tiered

question was considered to be one item, as was each part of a multi-tiered question. For

example, the Bonding posttest had six single-tiered questions (six items) and four two-

tiered questions (eight items, for the purposes of reliability testing), for a total of 14

items. Questions were removed until coefficient alpha reached at least 0.50. For the

Bonding posttest, that warranted removing 5 items (one single tiered question, and both

parts of two two-tiered questions). This left questions 1, 2, 4, 7, 9, and 10 to be used for

the posttest comparison of group means. The resultant coefficient alpha was 0.52.

Following a similar scheme, the PC posttest began with 12 items. Three items were then

removed, questions 3 and 7, and the second tier only of question 8. The remaining

question were then 1, 2, 4, 5, 6, 8 (first tier only), and 9. The internal consistency for

these remaining items was $\alpha = .53$.   Finally, because the coefficient alpha was .59 using

all of the original CC questions, none of those posttest items were discarded.

   Comparison of means. Table 5 shows the result of the t-test for independent

means comparing the collective scores of the wiki and NI groups. Although the wiki

group ($n = 47$, $M = 4.24$, $SD = 2.14$) outperformed the NI group ($n = 94$, $M = 3.84$, $SD =$ 2.28), the result was not statistically significant ($t = .982$, $p = .328$, $df = 139$). Cohen's d was low at 0.18. Thus, hypothesis 1, that the wiki group would outperform the normal instruction group, is not supported.

Table 5

Mean Posttest Scores (Collective Scores from Three Activities)

Wiki (n = 47)	Normal Instruction (n = 94)	t	p	df
4.24 (2.14)	3.84 (2.28)	.982	.328	139

Note: Standard deviations appear in parentheses below means.

Posttest (by activity). To further illuminate the posttest results, a comparison of means was done for each activity independently.

Bonding. In the case of the first wiki activity, Bonding, the wiki group ($n = 17$, $M = 3.82$, $SD = 2.59$) had a very slight advantage over the NI group ($n = 31$, $M = 3.60$, $SD = 1.95$). The result, however, was also statistically insignificant ($t = .334$, $p = .740$, $df = 46$). Cohen's d was .10.

Physical Changes. In the PC activity, the NI group ($n = 32$, $M = 5.01$, $SD = 2.34$) actually did better than the wiki group ($n = 16$, $M = 4.67$, $SD = 2.22$). Again, however, the results was statistically insignificant ($t = .493$, $p = .624$, $df = 46$). Cohen's d was 0.15.

Chemical Changes. Contrary to the other two activities, the difference in means for the CC activity was statistically significant ($t = 2.88$, $p = .027$, $df = 43$). The wiki group ($n = 14$, $M = 4.25$, $SD = 1.35$) outperformed the NI group ($n = 31$, $M = 2.88$, $SD =$

2.03) such that the effect size was almost three-quarters of a standard deviation (Cohen's

$d = .74$). The posttest results by activity are summarized in Table 6.

Table 6

Mean Posttest Scores (by Activity)

	Wiki[1]	Normal Instruction[2]	t	p
Bonding	3.82 (2.59)	3.60 (1.95)	.334	.740
Physical Changes	4.67 (2.22)	5.01 (2.34)	.493	.624
Chemical Changes	4.25 (1.35)	2.88 (2.03)	2.88	**.027**

Note: Standard deviations appear in parentheses below means. [1]$n_{bonding} = 17$, $n_{physical} = 16$, $n_{chemical} = 14$; [2]$n_{bonding} = 31$, $n_{physical} = 32$, $n_{chemical} = 31$. **Bold** indicates statistically significant result.

The superior posttest performance of the wiki group on the chemical changes

activity was underscored by the opinion of the teacher, described during the CC teacher

interview:

> The class period that did the [Chemical Changes] wiki had a better understanding
> of just like what a solution looks like and even in their [precipitation reactions]
> lab reports…they showed they had a better understanding of what was going on in
> the solution.

She went on to suggest that in the CC activity, the wiki students "showed a much greater

understanding of the content", emphasizing the importance of how the wiki activity

required evaluating the "zoomed in particle structure". Because of this, I took a closer

look at the results from questions five and six from the CC posttest. These two questions

both dealt with submicroscopic (i.e. "zoomed in") representations of precipitation

reactions. Comparison of the means (for these two questions only) between the wiki and

NI group were striking. The wiki group's ($n = 14$, $M = 1.50$, $SD = .20$) outperformance of the NI group ($n = 31$, $M = .55$, $SD = .85$) was statistically significant ($t = 3.59$, $p <$ .001, $df = 43$) and Cohen's d was very high at 1.33. The difference in means of 0.95 between wiki and NI, for these two questions alone, accounted for almost 70% of the 1.37 mean difference for the CC posttest at large. Furthermore, that these two questions were targeting the same underlying concept (that of understanding submicroscopic representations of precipitation reactions) was exemplified by the high coefficient alpha of .84 for the pair.

Questions five and six from the CC posttest were based on a study which identified student misconceptions about the submicroscopic nature of precipitations reactions (Kelly et al., 2009). Given the significantly better performance of the wiki group on these two questions, I distilled the results even further to determine if, in addition to having more correct responses, the wiki students also had an advantage in overcoming misconceptions. Results suggested wiki students were able to overcome misconceptions considerably better than the normal instruction group for three of the four answer choices dealing with misconceptions. For example, for choice "a" in question five, 35.71% of the wiki students had the misconception on the pretest and only 7.14% on the posttest. For the NI group, roughly the same amount had the misconception on the pretest as the wiki group (38.71% compared to the 35.71%), but on the posttest, however, the number of NI students who demonstrated the misconception actually increased to 64.52%. This result in favor of the wiki group is consistent with choice "b" from question 5 and choice "d" from question 6. That is, these choices also favored the wiki group's ability to overcome misconceptions (see Table 7). All three of these choices

address the misconceptions, in whole or in part, that ionic compounds exist as molecular

pairs either in aqueous form or as a precipitate.

Table 7

Number of Students Selecting Choice for Misconception

	Pre	%Misconception	Post	%Misconception	%Change
[1]Choice5a-Wiki	5	35.71	1	7.14	*-28.57*
[1]Choice5a-Normal	12	38.71	20	64.52	25.81
[1]Choice5b-Wiki	6	42.86	0	0.00	*-42.86*
[1]Choice5b-Normal	7	22.58	1	3.23	-19.35
[2]Choice6b-Wiki	2	14.29	4	28.57	14.29
[2]Choice6b-Normal	8	25.81	11	35.48	9.68
[1,2]Choice6d-Wiki	5	35.71	0	0.00	*-35.71*
[1,2]Choice6d-Normal	16	51.61	9	29.03	-22.58

Note: $n = 14$ for wiki group, $n = 31$ for normal instruction group. *Italics* indicates favorable %Change for wiki group over normal instruction.
[1]Misconception is that aqueous ionic *reactants* are molecular pairs prior to being mixed.
[2]Misconceptions are that the aqueous *"product"* exists as molecular pairs and that precipitates exist as molecular pairs and not three-dimensional lattices.

To determine if there was an association between group membership (wiki or NI)

and ability to overcome this misconception, a Chi-square test for independence was run.

First, for choices "a" and "b" from question five, the answer frequency for these was

combined because they address the same misconception. Using Fisher's Exact Test

because the expected frequency of one cell was less than 5, the wiki and NI groups were

determined to be equivalent in regards to the number of students who possess the

misconception on the pretest ($p = .321$). However, for the posttest (which had all cells

with expected values over 5), a Chi-square test for independence (with Yates Continuity

Correction because of the 2 x 2 table) indicated there was a significant association

between group status and those who possessed the misconception, χ^2 (1, $n = 45$) = 11.85,

$p = .001$. In other words, the wiki group was significantly better at overcoming the misconception that aqueous ionic *reactants* exist as molecular pairs. The effect size was *phi* = .561. This is large according to Cohen's benchmarks (Pallant, 2010, p. 220).

The preceding paragraph accounts for only two of the four choices which dealt with precipitation reaction misconceptions. Choice "d" from question 6 addresses two misconceptions at once (aqueous "products" of precipitation reactions exist as molecular pairs and the precipitate itself exists as molecular pairs) and therefore, because of confounds, was not included in the analysis. For the fourth answer choice dealing with misconceptions (choice "b" for question 6), both groups had a slight increase in the number of students who possessed the misconception that the aqueous "product" of precipitation reactions exists as molecular pairs. Chi-square analysis indicated the groups were statistically equivalent on both pre- and posttest, however. For the pretest, using Fisher's Exact Test, $p = .469$. For the posttest, also using Fisher's Exact Test, $p = .743$.

Summary. Although the difference between wiki and NI groups was not statistically significant for the overall analysis, the quantitative results from the study demonstrate considerable differences in outcomes among the three activities. The greatest contrast exists between the second and third activities, PC and CC. The NI group outperformed the wiki group (albeit, not in a statistically significant manner) on the PC posttest, whereas the wiki group did significantly better on the CC posttest. Furthermore, the CC wiki activity appeared to be a valuable tool in helping students overcome a common misconception. Therefore, in order to explicate what might have led to these disparate results, the qualitative results which follow will highlight the distributed scaffolding for these two activities in particular.

Qualitative results (first research question). This section will be divided into two subsections, both of which will be geared toward highlighting similarities and differences between distributed scaffolding from the PC and CC activities. The first subsection will cover complete topic sequences. That is, two groups were chosen, one from PC and one from CC, to see how wiki knowledge building evolved for a particular topic, from start to finish. This blanket coverage is essential in order to provide the reader the "big picture" in which the entirety of the results needs to be viewed. For example, we will see that even for the higher performing groups, peer editing of wiki content and discussion forum communication was extremely limited.

The second subsection will describe representative samples of the three primary characteristics of scaffolding: intersubjectivity, calibrated assistance, and fading. In a larger context, the goal of this section is to inform the quantitative results of the first research question.

Complete topic sequences. Purposive sampling was used to select two groups for analysis. Patten (2012) describes purposive sampling as selecting "individuals who are likely to have relevant information" (p. 149). Both groups selected offered some of the richest interactions among group members, relative to other groups in the study. Many groups were indeed characterized by very poor online collaboration and variable face-to-face collaboration. However, the two groups selected here, although still demonstrating considerably less than ideal online interaction, nevertheless had relatively dynamic face-to-face discussions. The two groups are not representative because the objective of this section is to provide the reader with best case scenarios. That is, to demonstrate some of the most effective collaboration in the study, and at the same time, highlight how even

that had considerable shortcomings. The results which follow this section, on the other hand, will employ purposive criterion sampling such that representative samples are chosen to represent the data at large.

The group selected to represent PC will from here on be referred to as PC-1, because it was Group 1 (of four) from the PC activity.   Although the group average rubric score for PC-1 was higher than the group average of the three other PC groups, they had a lower group average on the posttest then the collective average of all four PC groups. Although the activity rubric was demonstrated to have a small but significant correlation between posttest score and rubric score ($r = .294$, $p = .045$), the fact that PC-1 performed best according to the rubric criteria, and less than average according to the posttest results, suggests the rubric was less than perfect. One possible reason is the rubric may have placed too much weight on group score over individual score. That is, a group dominated by one or two strong performers could artificially inflate the score for all group members. Therefore, PC-1 was selected to contrast the selected CC group because, in addition to relatively engaging face-to-face discussions, something still was lacking that was not immediately evident based on the rubric score alone. PC-1 members include four girls: Daniela, Luciana, Mariana, and Valentina.

The CC group selected for this complete topic sequence comparison will be referred to as CC-2 (because it was Group 2, of four, for the CC activity). Like PC-1, CC-2 also had the highest rubric average for their respective activity. Contrary to PC-1, however, CC-2 also had the highest average posttest score among all CC groups. Therefore, an analysis of the distributed scaffolding patterns of CC-2 might provide insight into their relatively strong performance, especially as it compares to PC-1. CC-2

had only three members, two girls and one boy: Isabella, Sofia, and Santiago.

The topics selected to be included in these complete topic sequences represent the content from one wiki page of each activity. For PC, the topic chosen was Topic 1 (see first two pages of Appendix Q), and for CC, also Topic 1 (see first page of Appendix R). These were selected because they both offered multiple instances of distributed scaffolding. For clarity, both Topic 1 from PC and Topic 1 from CC will be described in two parts respectively. That is, first the actions of PC-1 for Topic 1 part "a" (generally referred to hereafter as Topic 1a) will be discussed, followed by the same group's efforts at Topic 1 part "b" (Topic 1b). After that, CC-2 collaboration on the CC Topic 1 part "a" (Topic 1a) and Topic 1 part "b" (Topic 1b) will be described in turn.

Physical Changes Group 1 (PC-1), Topic 1a. The template content for PC Topic 1a is shown in Appendix Q. Topic 1a deals with the common misconception that substances decompose when changing from liquid to gas, or solid to gas. The bulleted numbers which follow represent sequential episodes. For example, the introduction day scenario for Monday 11/26/12 which immediately follows represents Episode 1 for PC-1.

1. Introduction Day, Monday 11/26/12

Two reasons might explain, in part, why PC-1 never discussed Topic 1a on the introduction day. First, the class got off to a slow start. The class began in the regular classroom. The teacher introduced the activity, to the class as a whole, in a manner largely reflected by the teacher "Cheat Sheet" for PC (see Appendix M). Her presentation did not begin, however, until after roughly 10 minutes had passed. Second, this particular period was shortened to 40 minutes from the usual 50 due to a school assembly. Therefore, once the students moved from the regular classroom to the computer lab,

limited time remained. The only small group discussion remotely related to Topic 1a

dealt with Valentina assisting Daniela and Luciana on how to add their name to their

assigned topics (Topics 1b and 1d respectively). Valentina, who along with Mariana

would prove to be the group's most productive members, had already added her name to

Topic 1. All four group members were present for the introduction day.

2. Wiki History (Edit #1), Author: Valentina, Tuesday 11/27/12 7:03 PM

The day after the introduction day, Valentina adds her first substantive content.

She correctly identifies Change #4 as representing the sublimation of dry ice (see Figure

1; red shaded text indicates deletions, green shaded text indicates additions). Her

explanation is credible as well, emphasizing "the atoms keep the same structure".

However, perhaps due to the question being poorly phrased, she mentions several times

the phrase "complete gas". This is likely due to the question asking which diagram

represents "complete sublimation". The term "complete" was included on the template

simply to explain why no solid was left in the container after sublimation, and is

incidental to addressing the misconception.

3. Wiki History (Edit #2), Author: Valentina, Friday 11/30/12 8:34 PM

Several days later, Valentina reverses herself and now suggests change #3 is the

correct choice (see Figure 2). She seems to have been misled again by the term

"complete" as she now adds it in capital letters to explain her change of mind. She also

embeds a YouTube video which shows engaging dry ice demonstrations ("Dry Ice,"

2010; video screen shot not shown in Figure 2).

4. First Teacher Discussion Post, Wednesday 12/5/12 10:21 AM

Figure 1

Episode 2 PC-1 Topic 1a: Wiki History (Edit #1)
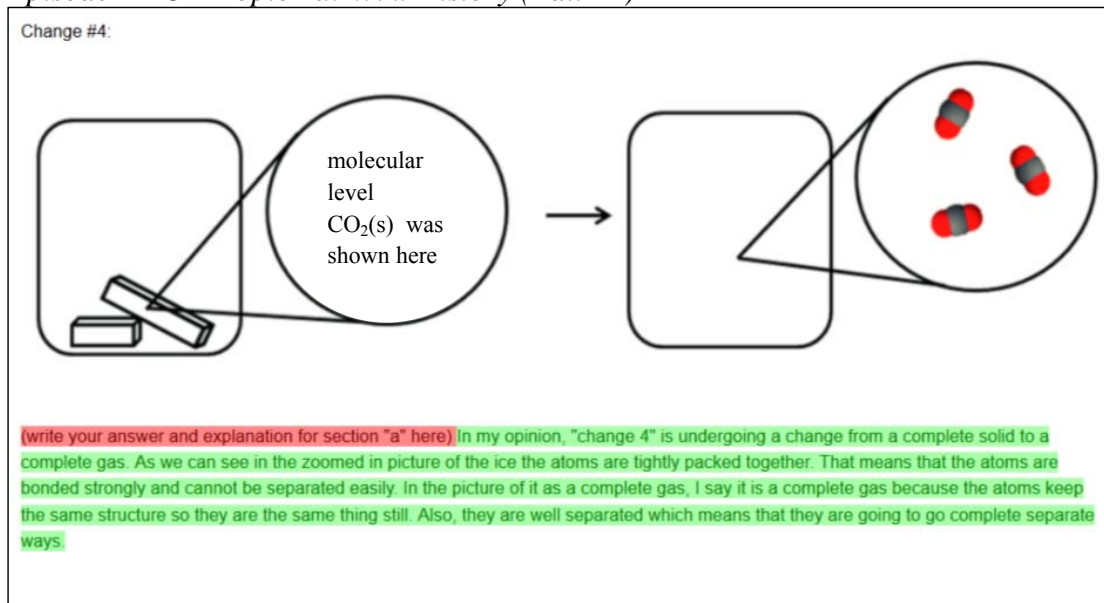
Note: Molecular level image of dry ice not shown to avoid potential copyright infringement. The image had many closely packed CO_2 molecules (see "Carbon-dioxide-crystal-3D-vdW.png," n.d.). All other molecular models in this document, such as the three molecules on the products side of the equation here, were created by the researcher with ChemSketch (colored atoms from the wiki pages, like the ones here) or Microsoft Word (black, white, and grey atoms from the pre/posttests).
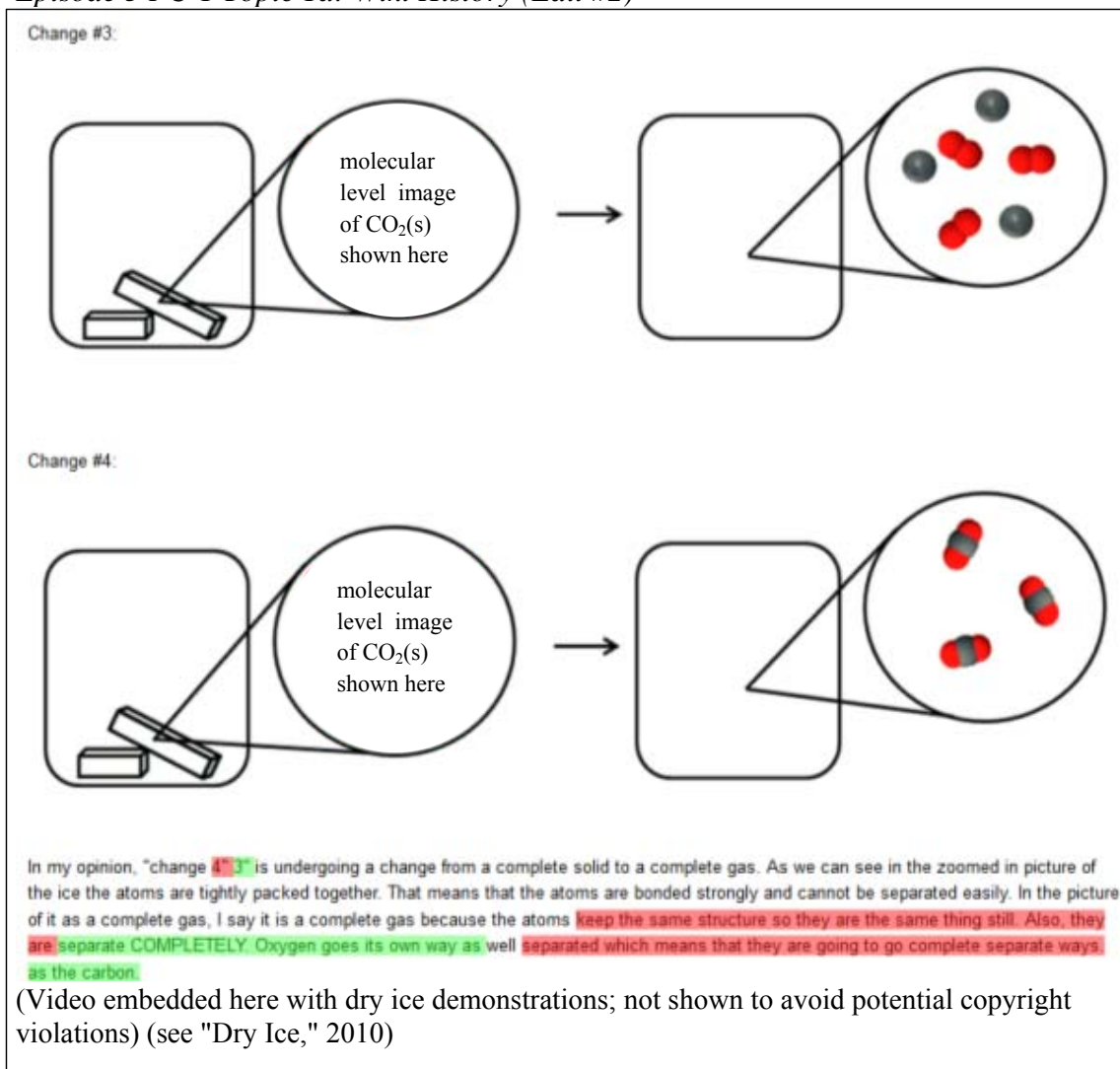
In her first discussion forum posting, the teacher first tries to steer the group from focusing on the term "complete"[13]. She also calls their attention to the fact that the initial choice of change #4 was the correct one. The teacher then provides calibrated assistance. She writes, "Change #4 is correct because 'each MOLECULE keeps the same structure when it becomes a gas, one carbon atom surrounded by two oxygen atoms'". In this excerpt the teacher emphasizes the word "molecule" over the word "atom" and includes additional text the students might consider incorporating. The teacher then concludes the feedback by reminding the students to "add a brief explanation that ties in

---

[13] Although Valentina was the only contributor to the page thus far, the teacher feedback is intended for the group as a whole. A fully collaborative effort, with all students editing all pages, was intended to begin at this point.

the video with the overall topic".

Figure 2

Episode 3 PC-1 Topic 1a: Wiki History (Edit #2)

In my opinion, "change 4 3" is undergoing a change from a complete solid to a complete gas. As we can see in the zoomed in picture of the ice the atoms are tightly packed together. That means that the atoms are bonded strongly and cannot be separated easily. In the picture of it as a complete gas, I say it is a complete gas because the atoms keep the same structure so they are the same thing still. Also, they are separate COMPLETELY. Oxygen goes its own way as well separated which means that they are going to go complete separate ways. as the carbon.

(Video embedded here with dry ice demonstrations; not shown to avoid potential copyright violations) (see "Dry Ice," 2010)

Note: Molecular level image of dry ice not shown to avoid potential copyright infringement. The image had many closely packed CO_2 molecules (see "Carbon-dioxide-crystal-3D-vdW.png," n.d.).

5. Midpoint Day, Wednesday 12/5/12

Valentina, the author of the original content for this topic, was absent on the midpoint day. Gathered in the computer lab, the other three members of PC-1 discussed the topic. Early in the period, the students were drawn to the embedded video. The

discussion that follows clearly demonstrates it engaged them, with comments like "That's cool" and "Now we know what they use in the movies":

Luciana:	It's just him cutting it? (probably referring to the dry ice being cut)
Daniela:	Yes.
Luciana:	It's doesn't cut. Oh he's showing that, oh yeah.
Daniela:	That was easier. (likely referring to when he used a hammer and screwdriver to pry it apart)
Luciana:	That's cool.
Luciana:	Is it hot or is it cold?
Mariana:	It's cold.
Daniela:	mmm hmmm.
Luciana:	It looks hot.
Luciana:	Oh and it wears off. It's wearing off, right?
Girl:	Yep.
Luciana:	That's cool.
Mariana:	The water must be hot.
Daniela:	You can see like the drops.
Luciana:	Oh, that's cool, that's gonna take out the fire. (carbon dioxide gas was used to extinguish a small flame)
…	
Daniela:	Now we know what they use in the movies.
Luciana:	What they use in what?
Daniela:	Movies.

Daniela: Doesn't it look like it?

Luciana: Yeah.

Luciana: It looks like that's a whole bunch of liquid falling out right and it's actually smoke.

Luciana: That's so cool. (the other two students echo similar sentiments simultaneously)

Luciana: That looks like, like its wet but its smoke. That's cool, or fog or whatever it is.

In spite of the unmistakable appeal of the video, at no point does the group discuss the primary concept for Topic 1a. Even after commenting about "wearing off" and "falling out", seemingly prime opportunities to discuss how this relates to the misconception that substances do not decompose upon changing to a gas, the group fails to do so.

Later in the discussion, when discussing Valentina's incorrect choice of Change #3, Mariana contends she believes the best choice was Change #4 (the correct choice). It is not readily apparent if Mariana had previously read the teacher feedback. What does seem clear is that the group, as a whole, does not read the teacher posting until near the end of the period. At this point, after reading the teacher's comments, they are reassured that Mariana was correct. However, they never discuss why Change #4 is the better choice and they never edit the topic. In fact, for the remainder of the activity, only Valentina and Mariana make changes to this topic based on the teacher feedback. Daniela and Luciana do not edit the topic in any way, in spite of the rubric requirement to make one significant change to each topic.

Regarding this topic, the only interaction with the teacher during the midpoint day

face-to-face was brief. The students inquired whether or not the teacher had seen the video. Jody replied she hadn't had the time to watch it in its entirety (the video was over 4 minutes long).

6. Wiki History (Edit #3), Author: Valentina, Thursday 12/6/12 8:22 AM

The day after the midpoint discussion, Valentina acts on the teacher's calibrated assistance from the discussion forum and revises her choice back to her original response of Change #4 (the correct choice). She also begins to deemphasize the focus on "complete" gas by deleting the capped "COMPLETELY" and she returns to her original description of the atoms staying "in the same structure" (see Figure 3).

Figure 3

Episode 6 PC-1 Topic 1a: Wiki History (Edit #3)

Furthermore, she adds her first description that attempts to tie in the video with the topic. She writes, "This video shows that the carbon dioxide goes from a solid to a complete gas and it completely skips the liquid part of the process. And, the compounds are not breaking up". With this, she demonstrates an unwillingness to abandon her "complete" gas emphasis. At the same time, however, by writing "the compounds are not breaking up" she appears to understand the fallacy of the primary misconception being addressed.

7. First (and only) Student Discussion Post, Author: Valentina, Friday 12/7/12 2:19 PM

Valentina wrote "I edited everyone's wiki a little. Luciana, i [*sic*] don't think yours needed that much editing, it was good". This represents the only student posting in the discussion forum and reflects the very limited online peer-to-peer communication that occurred in general, for all groups, on all three activities (this in spite of the fact that students received extra credit if they posted a message).

8. Wiki History (Edit #4), Author: Mariana, Friday 12/7/12 6:22 PM

Here, Mariana makes the one and only edit not contributed by the original author, Valentina. Her changes are noteworthy. By noting that it is the molecules that separate, and not the atoms, and retaining the concept that the basic unit CO_2 remains unchanged, she demonstrates sound understanding of the concepts (see Figure 4). She appeared to have benefitted not only from the calibrated assistance from the teacher posting (recall, Jody emphasized it was the "molecules" that kept the same structure), but also the framework already contributed by Valentina. Mariana does not edit the description of the video.

Figure 4

Episode 8 PC-1 Topic 1a: Wiki History (Edit #4)

In my opinion, "change 4" is undergoing a change from a complete solid to a complete gas. As we can see in the zoomed in picture of the ice the atoms are tightly packed together. That means that the atoms are bonded strongly and cannot be separated easily. In the picture of it as a complete gas, I say it is a complete gas because the molecules separate but the carbon atom and the oxygen atoms separate, yet, stay in the same structure, as in carbon dioxide. for Co2.

9. Second Teacher Discussion Post, Saturday 12/8/12 10:44 AM

The teacher Jody again reminds the group to shift the emphasis, for both the description of why Change #4 is the correct choice, and for the description of the video. She suggests they emphasize "retaining the SAME STRUCTURE, not on something being 'complete' or not". She also recommends they clarify the comments about the

video so as to demonstrate they fully understand what they mean when they write "the compounds are not breaking up". She continues with a sentence starter, "So you might want to edit your phrasing to indicate something like 'we can't see the molecules because they are too small, but IF we could see the molecules, we would see (you complete the phrase)'".

10. Wiki History (Edit #5), Author: Valentina, Tuesday 12/11/12 6:03 PM

Valentina makes the final edits. She seems to benefit from the teacher's ongoing assessment, which in turn led to the Jody's revised support in the second teacher posting. In the first paragraph, Valentina again deemphasizes her "complete" gas theory (although not entirely)(see Figure 5).

Figure 5

Episode 10 PC-1 Topic 1a: Wiki History (Edit #5a)

In my opinion, "change 4" is undergoing a change from a complete solid to a complete gas. As we can see in the zoomed in picture of the ice the atoms are tightly packed together. That means that the atoms are bonded strongly and cannot be separated easily. In the picture of it as a complete gas, I say it is a complete gas because the molecules separate separate, but the carbon atom and the oxygen atoms stay the same for Co2.

In the paragraph describing the video she completely removes references to a "complete" gas and she adds a sentence as per the teacher's recommendation (Figure 6).

Figure 6

Episode 10 PC-1 Topic 1a: Wiki History (Edit #5b)

This video shows that the carbon dioxide goes from a solid to a complete gas and it completely skips the liquid part of the process. And, the compounds are not breaking up.
Unfortunately, we can't see the molecules going into the air because of their tiny size. IF we could see the molecules, we would see particles of CO2 going up.

It is important to emphasize again that Daniela and Luciana contribute no content whatsoever to this topic. Further, there is no indication they read or reflected on what

Valentina and Mariana wrote and posted. During the focus group for PC-1, both Daniela and Luciana provided some insight into their lack of participation. Both suggested they would get "offended", at least at first, if another group member edited content they had originally posted. They agreed that, in part, this explains the limited amount of editing generally, for all groups. Furthermore, Luciana added "I think also because people, I don't think people want to go and change other people's work. I think that's just an extra step for people. Oh, I just finished mine. Oh, now I have to go fix the other persons". Here she seems to be associating elements of collaboration with unfairness.

Luciana, who had the most to say during the focus group, provided further insight on her lack of participation. When asked why she hadn't made revisions to her own original topic (Topic 4, not discussed yet), in spite of having multiple opportunities to receive calibrated assistance either face-to-face or in the discussion forum, she commented "I don't think that's because I thought [my group members] weren't right, or [the teacher] wasn't right. That's because I just never, I either forgot or I just never finished". She goes on to say "that's just me being a slacker" and that she "never really checked anything" the teacher wrote. Therefore, aloofness toward the activity, more than anything, might explain her relative inactivity. This may have been exacerbated by the fact she was absent when I provided the wiki introduction at the start of the school year by introducing how to navigate and use the wiki tools. She said, because of this, "I didn't get it and I came back and I was like, what's going on?" This excuse is contradicted, however, by the considerable amount of content she did manage to post for *her* original topic.

In concluding this first of four complete sequences, it is worthwhile to pause

briefly and highlight two attributes demonstrated here that are characteristic of all groups, in all three activities (Bonding, PC, and CC). One, discussion board communication among students was almost non-existent (save isolated and inconsequential posts such as Valentina's in Episode 7 above). Second, editing of topics, by someone other than the original author, was infrequent. Both of these attributes occurred in spite of rubric incentives intended to avoid them.

Physical Changes Group 1 (PC-1), Topic 1b. We now move to the second of four complete sequences. The template content for PC Topic 1b is shown in Appendix Q. Topic 1b, like Topic 1a, deals with the misconception that substances decompose when changing into a gas. Topic 1b differs in that the focus here is to explain the concepts in a creative manner.

1. Introduction Day, Monday 11/26/12

During the whole group session in the regular classroom, the teacher asked the students to brainstorm about creative ways of explaining the misconception. After this, students moved to the computer lab. Based on subsequent small group dialogue for PC-1, the brainstorming activity was successful. Valentina, Mariana, and to a much lesser extent Daniela, demonstrate their ideas for creative explanations:

Valentina:	What could I do? I'm thinking, because I was thinking like an example maybe a divorce and like what the child you know like (inaudible brief few words).
Mariana:	I was thinking high school when she said that.
Valentina:	High School?
Mariana:	Yeah like when we're in high school like I don't talk to that much

people.

Valentina: But you're still the same.

Mariana: Oh, OK, I see what you're saying.

…

Valentina: For that one you could maybe um. It would be like a pattern of

shapes. You know how you can make different patterns like

shapes. It could be like square, triangle, square, triangle. Or you

can make square, circle, triangle. The shapes are still the same it's

just.

Mariana: Changing.

Valentina: Yeah, the order.

Mariana: I think that's good.

In spite of the limited time available during this abbreviated session (recall this school

day had shortened class periods), the students manage to have a discussion that clearly

has them off to a good start.   They are already considering several creative ways to

explain how substances maintain the same composition once they become gases. The

fact that these specific ideas (divorce, high school, pattern of shapes), in the exact form

represented here, are never incorporated into the wiki does not diminish the efficacy of

the exchange. Note again, as with Topic 1a, it is Valentina and Mariana who carry the

discussion. Luciana never engages the others in a discussion concerning Topic 1b. The

lack of time is likely the main reason why no interaction regarding Topic 1b occurs this

day between the teacher and the group.

   2. Wiki History (Edit #1), Author: Valentina, Monday 12/3/12 8:24 AM

One week after the introduction day, content is first added to Topic 1b. Valentina, to whom the topic was originally assigned, gets off to a good (albeit delayed) start. With her analogy of a couple that splits up, yet each retaining their individual characteristics, she appears to understand the main objective that when substances change from liquid to gas, or solid to gas, their particles rearrange, but each molecule retains its individual characteristics (see Figure 7). Her first paragraph is completely accurate. Note the analogy of a couple splitting, which is retained in various forms henceforth, is fairly close in spirit to the divorce analogy she mentioned during the introduction day. Further evidence, perhaps, that the brainstorming activity during the whole class introduction provided a good jump start.

Figure 7

Episode 2 PC-1 Topic 1b: Wiki History (Edit #1)

When substances change state, they don't necessarily break down completely. For example, water (H2O) and carbon dioxide (CO2) when they change into a gas they don't go into the atmosphere as hydrogen going one way and oxygen going the other way. Same with carbon dioxide. they go in to the air as H2O and CO2
Let's say to people go out. Before they were a couple and everyone saw them together, all the time. Those two people, although, they are not together, they are still the same people on the inside and out. Nothing changed.

3. Wiki History (Edit #2), Author: Valentina, Monday 12/3/12 6:23 PM

Later that day, Valentina makes another nice effort. Her initial sentence is improved by emphasizing the relevant change of state is to a gas. She also embeds an excellent image of two friends going separate ways, and explains how they are still the same people after parting (see Figure 8). As with Topic 1a, the fact that no other group members have contributed to Topic 1b at this point is to be expected. The intended online collaborative period, which starts on the midpoint day, had yet to begin.

4. First Teacher Discussion Post, Wednesday 12/5/12 10:21 AM

The calibrated assistance in the teacher post is mostly praise. It concludes by asking the group to consider shortcomings of the analogy:

> For section "b", just about everything is excellent because you focus on the fact that when a substance changes to a gas "they don't necessarily break down completely". You can even make this a stronger statement and get rid of the word "necessarily". I like the way you give the additional example of H_2O in addition to CO_2. That image of the two friends going separate ways is also very good and your explanation is just right. I would keep the image and explanation just the way it is. But like most analogies, it seems to me it has at least one flaw. So please also mention in what way this picture is NOT a good analogy for a substance changing into a gas.

Figure 8

Episode 3 PC-1 Topic 1b: Wiki History (Edit #2)

When substances change state, state into a gas, they don't necessarily break down completely. For example, water (H2O) and carbon dioxide (CO2) (CO2), when they change into a gas gas, they don't go into the atmosphere as hydrogen going one way and oxygen going the other way. way; they stay together as H2O. Same with carbon dioxide. they Both compounds go in to the air as H2O and CO2. Let's say to two people go out. Before are dating. When they were a couple and couple, everyone saw them together, all the time. Then they break up. Those two people, although, they are not together, they are still the same people on the inside and out. Nothing changed. physically or emotionally changed about the two people.

(image embedded here of two women parting ways; image withheld to avoid potential copyright infringement) (see "girls-walking.jpg," n.d.)

Another example is these two friends going separate ways.
You see how these friends are going separate ways, yet, they look the same and are still the same people.

5. Midpoint Day, Wednesday 12/5/12

Recall that only Daniela, Luciana, and Mariana were present for the midpoint face-to-face discussion. Early in the session, the latter two briefly mention Topic 1b. Luciana asks "What is that?" and her group member replies "Friends going separate ways". About 20 minutes later they return to the topic, with no input from Daniela. Luciana begins by reading the content posted by Valentina. The comment "nothing physically or emotionally changed about the two people" gets Mariana's attention. She interjects, "I would not say that's true". Rather than build off that critique and discuss

the analogies effectiveness, the pair focuses instead on how many points to award (groups were instructed to self-grade each topic, the intent being to promote deeper thought about the concepts and make them self-aware of what needed improvement):

Luciana: I think she got the creativity… She got these 13 points.

Luciana: And I think she, should we give her like?

Mariana: I'm not sure she explained it, like cause, we can understand because we've taken it somewhat but for someone who hasn't taken it they wouldn't really understand it.

Luciana: Well, I think she did a good job with her example.

Mariana: Yeah, her example, but this part.

Mariana: Remember, someone who hasn't taken chemistry.

With that commentary, Mariana demonstrates one characteristic of good intersubjectivity. That is, she seems to have a firm grasp of the goal of the activity, which was to explain the topic in a creative way to someone with a limited chemistry background. The dialogue continued:

Luciana: (again reading the content posted by Valentina in the first sentence which follows) They don't go into the atmosphere as hydrogen going one way and oxygen going the other way; they stay together. I think she did.

Mariana: Mmm hmmm. OK.

By "I think she did", Luciana meant she thinks Valentina explained it well. Mariana then backs down and appears to defer to Luciana's more outgoing personality (that Luciana was the most extroverted group member was apparent from this and other face-to-face

interactions, including the focus group). I agree with Luciana's insight that Valentina explained it well. However, it is not apparent from the dialogue that Luciana isn't more impressed with surface features of topic's content (such as the image of the two friends parting) rather than the underlying conceptual explanations. Perhaps what is missing here is more informative than what is laid bare. That is, it appears to be a missed opportunity for Mariana, who has stronger conceptual understanding, to provide peer calibrated assistance to Luciana. Also missing from this exchange is a contribution from the teacher that might have redirected the group[14], and encouraged Mariana to elaborate on her contention that "I'm not sure she explained it".

6. Wiki History (Edit #3), Author: Valentina, Thursday 12/6/12 8:22 AM

As she did for Topic 1a, Valentina makes an edit for Topic 1b a day after the midpoint. She implements changes based on the teacher's calibrated assistance in the First Teacher Post. For example, she removes the word "necessarily", attaches real names to her couples example (i.e. Zac Efron and Vanessa Hudgens, a.k.a. Zanessa), and she qualifies her image description by noting that the friends who part ways may, in fact, be changed on the inside (see Figure 9). This latter alteration successfully emphasizes the shortcomings of her analogy. Compounds which undergo a phase change to a gas, after all, essentially have identical molecular composition before and after the phase change (i.e. the friends may really have some changes to themselves after parting ways; the molecules would not have any changes after parting ways).

7. Second Teacher Discussion Post, Saturday 12/8/12 10:44 AM

The teacher again praises the effort and results. At the same time, she provides

---

[14] The teacher was likely assisting another group at the moment.

several paragraphs worth of calibrated assistance. One aspect of the revised support is pointing out why the Zanessa example is still flawed. Specifically, when Valentina uses a single couple (Zac and Vanessa) as an analogy for a substance changing from solid to gas (or liquid to gas), it could be misinterpreted as a single molecule breaking apart (i.e. decomposing). This would be reinforcing the misconception, not correcting it. Therefore,

Figure 9

Episode 6 PC-1 Topic 1b: Wiki History (Edit #3)

When substances change state into a gas, they don't necessarily break down completely. For example, water ($H2O$) and carbon dioxide ($CO2$), when they change into a gas, they don't go into the atmosphere as hydrogen going one way and oxygen going the other way; they stay together as $H2O$. Same with carbon dioxide. Both compounds go in to the air as $H2O$ and $CO2$.
Let's say two people are dating. For example, let's use Zac Efron and Vanessa Hudgens, they were known as Zanessa. When they were a couple, everyone saw them together, all the time. Then they break broke up. Those two people, although, they are not together, they are still the same people on the inside and out. Nothing physically or emotionally changed about the two people.

(image embedded here of two women parting ways; image withheld to avoid potential copyright infringement) (see "girls-walking.jpg," n.d.)

Another example is these two friends going separate ways.
You see how these friends are going separate ways, yet, they look the same and are still the same people.
This analogy might not be the best either because we never know if the people changed on the inside at all.

in the second part of the feedback the teacher gives two specific suggestions on how the analogy might be improved. Here is one:

> …you could possibly say "imagine" the two people (like Zac and Vanessa; or like the two women) are identical twins. And that each twin represents an *entire* molecule (i.e. each represents a molecule of HCl). This way, when they split apart, one HCl goes one way, the other HCl goes the other way and *everything* is still HCl (not H + Cl). Hence, a physical change!

Mostly though, the effort and results on this topic so far are exemplary. That is, at least for Valentina. None of the other three group members contribute content even though the collaborative phase of the activity is well underway.

8. Wiki History (Edit #4), Author: Valentina, Tuesday 12/11/12 6:03 PM

Hours before the final project is due, Valentina makes one final edit. Again, she does an excellent job at trying to implement the teacher's suggestions (see Figure 10). She replaces the image of the two friends parting ways with two separate images, one with a pair of young friends and another with a pair of older friends. She then goes on to describe how the two pairs get into an argument and then break up.

Figure 10

Episode 8 PC-1 Topic 1b: Wiki History (Edit #4)

The analogy still has its flaws, not the least of which is that it is not clear if Valentina understands that using two *identical* images of the same pair (just like two molecules of a substances are identical), instead of having two images each with a different pair, might work better. Nevertheless it is a solid effort by Valentina. Unfortunately, there is no evidence that the three other members of the group, after the midpoint discussion, are engaged in topic 1b at all.

Summary of PC-1 collaboration on Topics 1a and 1b. Three key aspects regarding distributed scaffolding are worth noting from the analysis of PC-1's

collaboration on complete sequences topics 1a and 1b. First, topics 1a and 1b were originally assigned to Valentina, and she put by far the most work into refining them. While the others were expected to edit her original content, Mariana was the only one to do so (her one edit on Topic 1a). Perhaps this suggests that calibrated assistance is needed for more than just content. That is to say, PC-1 seemed to need additional ongoing assessment and revised support that focused on making sure *all* group members were actively engaged on *all* topics.

Second, even when collaboration was good, it wasn't always on topic. For example, all present group members contributed to the lively discussion about the dry ice video. Not once, however, did they discuss the misconception intended to be addressed. Perhaps this suggests calibrated assistance was also needed to redirect students to the primary objective. Finally, fading did not occur. That is, there certainly was no transfer of responsibility in a non-abrupt, measured fashion (F. Wang & Hannafin, 2008). As we will now see in the complete sequences for CC-2, the chemical changes activity also lacked fading. However, because of the performance of the group as a whole, it was also less necessary.

Chemical Changes Group 2 (CC-2), Topic 1a. This will cover the third of four complete sequences. It is also the first of two dealing with a CC group. The template content for CC Topic 1 part "a" is shown in Appendix R. The Topic 1a for this activity deals with the misconception that aqueous ionic reactants exist as molecular pairs instead of independent ions.

1. Introduction Day, Wednesday 2/13/13

Unlike the physical changes introduction day, the chemical changes groups did not have an abbreviated period. The only discussion related to Topic 1a took place between Santiago and the teacher. The teacher provides calibrated assistance in the form of both ongoing assessment and revised support. The teacher combines the two to aid him in getting a sound initial footing into the topic. As they begin, they are referring to the three diagrams (the same three diagrams in Figure 11).

Teacher: Which one shows the aqueous sodium bromide?

Santiago: Aqueous is dissolved in water?

Teacher: Yeah it dissolves.

Teacher: Which one of those looks dissolved?

Santiago: This one. (referring to diagram #2)

Teacher: Why?

Santiago: Because they are all separated Miss?

Teacher: Yes, sir.

Santiago: This is a solid. (probably pointing at #1)

Teacher: That looks solid to me.

Santiago: Gas, no. (probably looking at #3)

Teacher: It could be a gas or maybe it, because it looks like there's a liquid level line...so you're going to pick which one you think it is and you're going to write it there and then briefly explain why you chose the one you did.

Here, Santiago demonstrates either some prior knowledge or the ability to catch on quickly. Sofia and Isabella, the group's other two members, did not discuss this topic
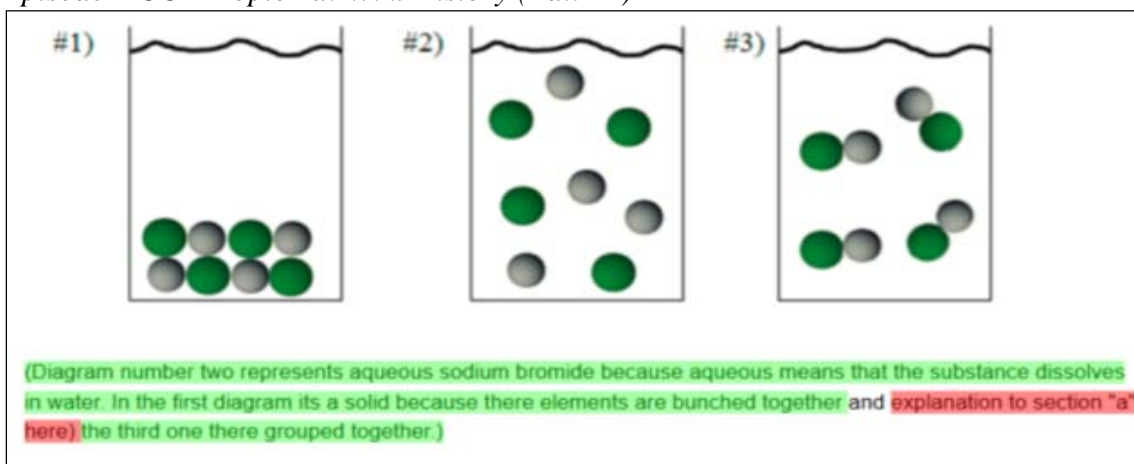
during the introduction day.

2. Wiki History (Edit #1), Author: Santiago, Wednesday 2/13/13 2:34 PM

Shortly after the teacher scaffolding, Santiago makes his first edit.

Everything he writes is accurate; including that diagram two represents aqueous

sodium bromide (see Figure 11). Lost in his brief description, however, is an

explanation of the key issue. That is, #2 is aqueous sodium bromide *because* the

ions are *completely* separated. It is not obvious he appreciates the distinction

Figure 11

Episode 2 CC-2 Topic 1a: Wiki History (Edit #1)

#1)   #2)   #3)

(Diagram number two represents aqueous sodium bromide because aqueous means that the substance dissolves in water. In the first diagram its a solid because there elements are bunched together and explanation to section "a" here) the third one there grouped together.)

between #2 and #3, both of which could represent aqueous substances. Only #2,

however, is ionic. It may be implied in his description of #3 as being "group together"

(as a means of contrasting it to #2).

3. Wiki History (Edit #2), Author: Santiago, Monday 2/18/13 10:33 PM

Five days later, a day before the midpoint discussion, Santiago makes minor

changes, but still fails to overtly emphasize the differences between #2 and #3 (See

Figure 12).

4. First Teacher Discussion Post, Tuesday 2/19/13 10:38 AM

The next day, just a couple hours before the midpoint face-to-face in the computer

Figure 12

Episode 2 CC-2 Topic 1a: Wiki History (Edit #2)

(Diagram number two represents aqueous sodium bromide because aqueous when something is aqueous it means that the substance dissolves in water. In the first diagram its a solid because there the elements are bunched together together, and the third one there the elemens are grouped together.)

lab, the teacher posts feedback. The calibrated assistance is geared toward getting the

group to clarify the differences between #2 and #3.

> Please just fix the ending of the first sentence a bit. If you say "…because when something is aqueous it means that the substance dissolves in water", that is true. But even diagram #3 can be thought of as something dissolved in water (i.e. something that wasn't ionic). So what is it about Diagram #2 that lets you know it represents an ionic substance dissolved in water? Hint: Focus on what it says in the first few sentences at the top of the page.

The last sentence of the posting directs the students to reread the top of the wiki page

where the teacher's template content states that aqueous ionic substances "exist as

independent ions in solution" and not "molecular pairs of ions".

5. Wiki History (Edit #3), Author: Sofia, Tuesday 2/19/13 1:59 PM

During the midpoint meeting, which marks the beginning of full online

collaboration (i.e. all students now responsible for editing all topics), Sofia takes the

initiative and edits what Santiago had previously added. This happens before the group

discusses the topic. Her edit is a minor, but not insignificant one, changing the word

"grouped" to "paired" (see Figure 13). It focuses the content directly on the

misconception that aqueous ionic substances do not exist as molecular "pairs". It is not

clear what prompted her to make the change. It possibly came from reading the teacher's discussion forum feedback. Recall, the teacher directed the students to the top of the page where the misconception about molecular *pairs* was explicitly stated. Granted, that discussion forum post was calibrated for Santiago, who at the time was the only individual to post content. Nevertheless, Sofia appears to benefit from it.

Figure 13

Episode 5 CC-2 Topic 1a: Wiki History (Edit #3)

> (Diagram number two represents aqueous sodium bromide because when something is aqueous it means that the substance dissolves in water. In the first diagram its a solid because the elements are bunched together, and the third one the elemens are grouped paired together.)

6. Midpoint Day, Tuesday 2/19/13

After being summoned by Santiago, the teacher reads from her discussion post to remind herself what she had written to the group. The discussion about the topic then commences:

Teacher:	So I just want you to say what makes, what about it lets you know that it represents an ionic substance dissolved in water?
Santiago:	So what is it Miss that lets me know? Because it is number 2, right?
Teacher:	It is number 2, you're right. So what makes number two different than number 3?
Santiago:	They're all separate Miss.
Teacher:	All separate, right.
Santiago:	This is a solid, right Miss? (probably pointing to #1)
Teacher:	Yep.

Teacher: So you just need to explain why it's 2 and not 3. Because the third

one could be dissolved too.

Santiago: Because these are paired. (line 9)

Teacher: Right.

Teacher: And you want them to be what?

Santiago: Separate.

Teacher: Completely separate. You just need to be very clear about that.

Santiago: So when something is aqueous it means something dissolved in

water. In the first diagram it is solid because the elements are

bunched together. Should I take that off Miss?

Sofia and Isabella: No, no. (both speak up immediately) (line 15)

Sofia: That's actually good. (line 16)

Teacher: You can leave that. Just say that, the second one, the thing that

makes them dissolved in water is that they are completely what?

Santiago: Separated.

Several points from this exchange are noteworthy. First, notice that Santiago

describes #3 as "paired" (see line 9 above), and not "grouped" as he had originally

written.   Earlier Santiago had read Sofia's edit. Thus, by now describing #3 to the

teacher as "paired", he is demonstrating how he benefitted from Sofia's peer scaffolding.

The fact that Sofia probably had not intended to scaffold a fellow group member is not

the point. The outcome is what we are concerned with.

Second, the teacher provides calibrated assistance by reiterating how the focus

should be on how ionic compounds exist as "completely separate" ions when dissolved.

Finally, and perhaps most importantly as a contrast to the PC-1 group, all group members are clearly paying attention. Sofia and Isabella, although not at the fore of the conversation, react quickly when Santiago questions his own explanation of #1. They remind him that his description of #1, the solid representation, is accurate and shouldn't be changed (see lines 15 and 16).

7. Wiki History (Edit #4), Author: Santiago (logged in as Sofia), Tuesday 2/19/13 2:02 PM

Santiago, logged in as Sofia (part of the dialogue, not shown above, suggests he must have made the edit by using the computer she was logged into), introduces the concept of "totally separated" which suggests he was listening carefully to the distributed scaffolding he just received from both teacher and peer. He still doesn't, however, explicitly convey that it is *ionic* compounds that are "totally separated' when dissolved (see Figure 14). As he typed, Sofia critiqued his spelling by stating "You spelled aqueous wrong", indicating she was clued in. It is unknown if the same could be said for Isabella.

Figure 14

Episode 7 CC-2 Topic 1a: Wiki History (Edit #4)

(Diagram number two represents aqueous sodium bromide because when something is aqueous it means that the substance dissolves in water. Also when something is aqueous it means that its totally separated. In the first diagram its a solid because the elements are bunched together, and the third one the elemens are paired together.) together and not completely separated.)

8. Second Teacher Discussion Post, Saturday 2/23/13 3:17 PM

Jody praises the group on their improvements. However, to draw their attention to the fact that it is *ionic* compounds that are totally separated when dissolved, she concludes with a fill-in-the-blank prompt:

…it is not always the case that just because something is aqueous, it totally separates (for example, sugar easily becomes aqueous, but it does NOT separate when dissolved). So just change your sentence a bit by filling in the blank "Also when (blank) is aqueous it means that its totally separated". What goes in the blank (hint: it's a specific type of compound)?

9. Wiki History (Edit #5), Author: Santiago, Monday 2/25/13 7:02 PM

A couple days later, just before the assignment was due, Santiago makes the final

edit. By replacing "something" with "NaBr" (see Figure 15) he is reacting to the

teacher's calibrated assistance in the second teacher posting. Although an improvement,

he also misinterpreted what the teacher was getting at. She was looking for "ionic

Figure 15

Episode 9 CC-2 Topic 1a: Wiki History (Edit #5)

(Diagram number two represents aqueous sodium bromide because when something is aqueous it means that the substance dissolves in water. Also when ~~something~~ NaBr is aqueous it means that its totally separated. In the first diagram its a solid because the elements are bunched together, and the third one the elemens are paired together and not completely separated.)

compound" to replace "something", which would indicate he had a more generalized,

abstract understanding of the concept. Instead, his answer doesn't make it clear whether

or not he realizes it can be *any* ionic compound, and not just one specific ionic

compound, NaBr. Sofia makes no additional edits after her one midpoint day change.

The third and final member of the group, Isabella, makes no edits to Topic 1a at any time.

The *almost* non-existent editing done by Sofia and Isabella on CC Topic 1a is not

dissimilar to the *complete* lack of editing demonstrated by Daniela and Luciana on the PC

Topic 1a. Both pairs fell considerably short of fully embracing the collaboration that

wiki technology facilitates. However, considering the one edit that Sofia did make, the

evidence that she was monitoring closely the edit Santiago made (when she checked his

spelling), and the evidence that both girls were quick to correct Santiago about his

suggestion that he alter a conceptual explanation he had previously written, all suggests a level of engagement beyond that demonstrated by Daniela and Luciana for their PC Topic 1a. In Daniela and Luciana's case, there was some engagement during the midpoint discussion, but neither then, nor at any other time did they evince concern with the misconception intended to be addressed.

Chemical Changes Group 2 (CC-2), Topic 1b. This section will cover the fourth and final complete sequence. The template content for CC Topic 1 part "b" is also shown in Appendix R. Topic 1b also deals with the misconception that aqueous ionic reactants exist as molecular pairs instead of independent ions. As opposed to Topic 1a, however, the objective is now to explain the misconception in a *creative* way.

CC-2 had no discussion about Topic 1b during the introduction day. Furthermore, Santiago, who was initially assigned to the topic, contributed no content before the midpoint. Therefore, the first episode below represents the First Teacher Post in the discussion forum, a couple hours before students met for the midpoint discussion.

1. First Teacher Discussion Post, Tuesday 2/19/13 10:38 AM

Noticing Santiago had yet to contribute content, the teacher encourages the group to collaborate and get going:

> For section "b", I don't see any content you've added yet. If you are stuck for ideas, discuss it with each other. Don't be afraid to be creative! Have some fun with it if you want. And if you use an analogy, remember it doesn't have to be perfect. Just make sure to explain the reasons it's a good analogy AND the reasons it's not such a good analogy.

Notable about this calibrated assistance is the reminder to be creative and not worry if an analogy is imperfect, provided the shortcomings are explained. We will return to this type of comment later in the Results chapter, as another means of contrasting the CC and

PC results in general.

2. Midpoint Day, Tuesday 2/19/13

Santiago talks to the teacher about his idea for a creative explanation. He

wonders if a Harlem Shake[15] video would be a good analogy for dissolved ionic

compounds:

Santiago: Should I put a Harlem Shake video in Miss?

Teacher: How does that help?

Santiago: I don't know cause [*sic*] there's like all settled and quiet and

they're sitting down Miss and then they start going crazy.

Teacher: OK. If you can explain that. Absolutely. It's your analogy, you

can do whatever you want. You just have to be able to say why it

works and maybe some reasons it doesn't.

Santiago: Some reasons maybe it doesn't work because people are dancing

together Miss.

Teacher: Could be what?

Santiago: People are dancing together. It's better when they go solo.

Teacher: Yeah, you're right.

Sofia: That would be good. (she laughs)

Teacher: That would be good.

Three points about this exchange are noteworthy. First, although Santiago again takes the

lead in discussing the concept with the teacher, Sofia demonstrates her support for

---

[15] The "Harlem Shake" is described by ABC News (2013) as involving two parts. First, only one person dances, an individual usually wearing a mask. The others in the room remain still, paying no attention to the dancer. Second, "when the bass drops", others join in on the dancing, often with costumes and props.

Santiago's creative idea, possibly demonstrating she is reflecting on the concepts.

Second, in the same spirit as her discussion posting, the teacher provides supportive

comments of the analogy, encouraging the group to use their idea and, at the same time,

remember to also point out shortcomings.   Third, in this case, reminding the group to

highlight shortcomings amounts to providing the ongoing assessment that is part of

calibrated assistance. For example, when Santiago responds, "Some reasons maybe it

doesn't work because people are dancing together Miss", the teacher would recognize

Santiago has a sound understanding of the analogy's weaknesses.

Throughout this exchange, although Isabella is not heard from, evidence suggests

she was paying attention. Several seconds later, she states "I haven't seen those",

referring to the Harlem Shake videos. Then shortly after that, she asks her group

members to explain the point of using that particular video:

Isabella:	What are you doing?
Sofia:	(incomprehensible)
Santiago:	I'm looking for the Harlem Shake OK?
Isabella:	I don't get the whole point of it?
Sofia:	We need to hear it.
Isabella:	What's the point of it?
Santiago:	(incomprehensible)
Isabella:	What's the point of it?

Perhaps the most important aspect of this exchange is what does not occur. Isabella's

multiple requests for clarification go unheeded. Neither Santiago nor Sofia explains

"what's the point of it".   This is a missed opportunity for peer calibrated assistance.

What is also clear, however, is that Isabella is interested and participatory, and we will see shortly in her focus group comments that sooner or later she was able to get her question answered.

A final aspect of the midpoint day discussion worth noting is the calibrated assistance the teacher provides Santiago related to posting a video. As she looks over his shoulder, she talks him through the process with procedural scaffolding such as "So right-click on it" and "Copy embed html". As we will see in the next episode, this assistance paid off that evening.

3. Wiki History (Edit #1), Author: Santiago, Tuesday 2/19/13 10:33 PM

Santiago embeds a "Harlem Shake" video and offers an explanation to go with it (see the explanation in Figure 16; video screen shot not shown):

Figure 16

Episode 3 CC-2 Topic 1b: Wiki History (Edit #1)

(write As your explanation about to section "b" here) see in this video "military edition of the Harlem Shake" the soldiers are all line up straight basically motionless and this will be on example of a solid sodium bromide because there not much going on. Later on in the video when the music starts the soldiers break up the line and start going crazy and this will represent sodium bromide in aqueous form.
(Harlem Shake video embedded here; not shown to avoid potential copyright infringement)(see "Harlem Shake (original army edition)," 2013)

Although a good effort at creativity, Santiago fails to mention the shortcoming that he seemed to recognize during the midpoint discussion. That is, it isn't the best analogy for dissolved ionic compounds because the soldiers do more dancing *in place* rather than moving around randomly. Or, as Santiago said earlier, it would be better if they went "solo" instead of "dancing together".

4. Second Teacher Discussion Post, Saturday 2/23/13 3:17 PM

In her second discussion forum posting, Jody calls the group's attention to the shortcoming that Santiago failed to mention:

> As for section "b", I like it! Great idea! If I were to be nitpicky, maybe you could just explain briefly that the Harlem Shake would be an even better representation of aqueous ionic compounds, like NaBr, if each soldier moved around more (i.e. didn't just "dance" in the same spot) just like each independent ion in a solution really floats all over the solution.

5. Wiki History (Edit #2), Author: Santiago, Monday 2/25/13 7:02 PM

Santiago adds the final edit (see Figure 17), reacting to the calibrated assistance offered by the teacher in her second posting. His explanation still leaves something to be desired, however. Rather than explaining the shortcoming that the video would be better if the soldiers were dancing all over the place, he phrases it as if the video *is* a good analogy because the "soldiers are moving all around the place". If you view the video, this contention seems to be an exaggeration. Nevertheless, it is possible Santiago did understand the problem, as evidenced by his comments from the midpoint discussion that the video was flawed because they are "dancing together" (i.e. implying they are *not* moving "all around the place").

As the activity came to a close at this point, neither Sofia nor Isabella made one edit to Topic 1b. They do address the topic in the focus group, however (because of availability issues, Santiago's focus group was at a different time/day then Sofia's and Isabella's):

Figure 17

Episode 5 CC-2 Topic 1b: Wiki History (Edit #2)

Sofia: Didn't we give our other partner the idea to do the Harlem Shake? We told him that would be a good one because they start together and then.

Isabella: They break apart yeah.

Sofia: We gave him the idea of using the video.

EO: How did you think of that one?

Isabella: It was popular recently when we were working on the wikis.

Here, Sofia and Isabella suggest the "Harlem Shake" video was their idea. If this is true, it suggests a higher level of engagement for the pair than their lack of editing revealed. Furthermore, by Isabella noting "They break apart", she demonstrates that she apparently did eventually get her question "What's the point of it?" answered.

Evidence exists, however, which refutes their contention that they gave Santiago the idea for the video. He certainly implies in his midpoint discussion above that it was his idea, not to mention he explicitly states it was when he was interviewed separately from the two girls:

EO: Can you think of any other instances of what the teacher did that was particularly helpful?

Santiago: For example, she, I'm pretty sure she told me I had to be more creative. Because at first I was, I mean I did look for some stuff but I was just going to put a random picture. But afterwards I was like we can just get footage. YouTube or something and we can just relate it to it.

EO: And is that how you came up with this one here, the "Harlem Shake"?

Santiago: Yeah.

EO: And she didn't give you that idea right? She just said generally look

              up for something new and it was you who had thought of that, right?

Santiago: Yeah.

Santiago's comment's leave the issue unresolved of who first suggested use of the

Harlem Shake video. For a collaborative project, however, this may be irrelevant. What

is evident is that all three group members, sooner or later, came to at least a partial

understanding of why it was a useful, if not flawed, analogy. Finally, Santiago appears to

have responded well to the teacher's encouragement to be more creative (recall, in the

first discussion posting, Jody suggested "Don't be afraid to be more creative!"). This is

evidence of the teacher fostering intersubjectivity. That is, by encouraging creativity,

students who respond well take more ownership of the task

    Summary of CC-2 collaboration on Topics 1a and 1b. The preceding complete

sequences for CC-2 Topics 1a and 1b have differences and similarities with PC-1 Topics

1a and 1b (the first two complete sequences covered above). Where the groups appear to

have diverged is related to degree of focus on the objective. The evidence suggests that,

at least at some point and to varying degrees, *each* CC-2 group member directed their

efforts towards understanding the misconception at hand. There is no evidence to support

this assertion for PC-1. Again then, it appears directing group members to stay focused

on the objective might be another aspect of calibrated assistance that would prove

fruitful. Regarding similarities, for all four PC-1 and CC-2 complete sequences, fading

did not occur. Another commonality is that both groups demonstrated almost unilateral

wiki editing. That is, the individual originally assigned to the topic, Valentina for PC-1

and Santiago for CC-2, made every edit, save one in each case. As noted earlier, perhaps

this suggests that calibrated assistance that focuses on group dynamics and participation

is equally as important as that which focuses on content.

Before moving on, it is worthwhile to share additional results relevant to the lack

of collaborative editing. Students from *all* focus groups (including those not mentioned

above, but described shortly in the next section) had reservations about either editing

someone else's content or having someone edit their content. CC-2 member Sofia

suggested she felt uncomfortable editing someone else's content because "you never

know if they'll get mad at you". PC-1 member Daniela, reacting to Luciana's comment

"I guess I get mad a lot when people change my wording", said she would "get offended"

if other student's edited her content.

There were instances in which students expressed fewer reservations about peer

editing, but they were always qualified. As one example, Isabella's comment expresses

her opinion as a CC-2 member:

> sometimes we would get mad at each other like when this person took out this
> thing, we were like "Oh why did you take it out", "Oh, it didn't fit in", when in
> your mind you thought this goes really good with this. Another person comes and
> just takes it out. But it does help because you get feedback from your other
> classmates. You think "Oh, I guess their right" and you start to look at it from
> their point of view and you start to help each other out so your work can be better.

Here, Isabella's initial negative reaction is tempered by eventually coming to realize

potential benefits. Nevertheless, she doesn't enthusiastically embrace the assignment

from the outset. These reservations are consistent with student attitudes expressed in the

literature review and perhaps, more than anything to follow, represent the biggest

obstacle to be overcome if classroom based wiki projects are to be effective.

Having now shared examples of four complete sequences, we will now turn to the second subsection on qualitative results which pertain to the first research question. That is, examples of the three defining characteristics of scaffolding: intersubjectivity, calibrated assistance, and fading. Some content will overlap with the data from the complete sequences. However, additional examples pertaining to other groups and other topics will also be introduced.

Scaffolding characteristics. This segment of the Results chapter will be divided into three sections: intersubjectivity, calibrated assistance, and fading. Examples will be provided that represent each. The examples are taken from four representative groups, using purposive criterion sampling. Two of the groups, PC-1 and CC-2 were described above. The other two groups are physical changes Group 2 (PC-2) and chemical changes Group 4 (CC-4). These two groups were selected for two reasons. First, selection of additional groups from PC and CC (as opposed to a Bonding group) will allow for further comparison between the disparate PC and CC posttest results. Second, both of these groups scored well *below* their respective class averages on the rubric criteria. For example, the average of the four members of PC-2 was 50.6 (out of 100), compared to the PC class average of 64.0. For the CC-4 group, the average was 60.9, whereas the CC class average was 67.3. These lower performing groups provide a balance to the higher performers in PC-1 and CC-2, described in the complete sequences section. Those groups scored well *above* their class averages on the rubric (but not necessarily the posttest). Thus, collectively the four groups provide a sample approaching representative. Group membership is summarized in Table 8.

Intersubjectivity. Intersubjective learning environments are characterized by a

teacher-learner relationship that is entirely collaborative. This is operationalized in three ways. One is by establishing combined ownership of the task (Puntambekar & Hübscher, 2005). The second is by having the learner understand the goal of the activity

Table 8

Group Membership

PC-1	PC-2	CC-2	CC-4
Daniela	Gabriela	Isabella	Camila
Luciana	Lucas	Santiago	Diego
Mariana	Mateo	Sofia	Samuel
Valentina	Victoria		Tomas

(Puntambekar & Hübscher, 2005). The third, described as the primary benefit by Wu (2010), is to "help learners to bridge the gap between the levels of current and prospective knowledge" (p. 32). These three characteristics, *combined task ownership*, *student understanding the goal*, and *knowledge bridge*, form the framework of the following intersubjectivity results. We begin with combined task ownership.

Combined task ownership was facilitated in all groups by providing the opportunity to be creative. As demonstrated above in the complete sequences, part "b" of each topic generally instructed students, "In a creative way (everyday analogy, poetry, creative video, etc...), explain to someone who doesn't have a strong background in chemistry that…". That statement would often conclude by addressing a particular misconception. Students had no limit on what form their creativity might entail, provided it could be communicated via the wiki.

In focus groups, when asked to describe the first thing that came to mind when deciding how to be creative, responses were varied. From PC-2, Victoria mentioned videos and Gabriela said "colors…like to catch their attention". Isabella, who we met

above in CC-2, suggested "I mainly thought like first for FIFA[16]". She was referring to Topic 4 (not described above in the complete sequences) in which the objective was to describe *spectator ions* in a creative way. She continued, "the spectator ions they just watch so it's like fans, they just sit there and watch the game and they don't contribute to the actual thing".

Isabella's focus on fans is noteworthy. The analogy is a good one. In fact, it is not uncommon for chemistry teachers to use the same (not restricted to *soccer* fans only). An unidentified student even mentioned the possibility of using that analogy during the whole group creativity brainstorming activity. Making the most of this analogy, Isabella appears to have thought deeply about the topic because she manipulated an image she posted on the wiki. In her focus group she said, "I just circled like where the people would be and where they should have been in the picture". Her photo editing was the only one to take place in all three activities. Recall that Isabella's participation in Topic 1 was limited, including not one edit. Based on her photo editing, and the two edits she made regarding spectator ions (as demonstrated on the wiki history pages; not shown here) it suggests a more active role on Topic 4 than Topic 1, the one we saw above in the complete sequences.

Topic 4 was not Isabella's originally assigned topic. That was Topic 3, where we would expect greater participation. Therefore, her higher level of participation on Topic 4 is important because the topic of spectator ions (Topic 4) overlaps considerably with the Topic 1 concept of aqueous ionic reactants existing as independent ions. Thus, perhaps the superior performance of the CC groups in general, and on the ability to overcome misconceptions in particular, is due in part to the fact that they had multiple

---

[16] Fédération Internationale de Football Association, the international soccer governing body.

opportunities to creatively engage the same underlying concept in different contexts. This overlap of topics applies to Topic 2 as well. Although focused on the structure of the ionic solid, rather than the ions in solution (as Topics 1 and 4 are), Topic 2 is similar to Topics 1 and 4 in that the counter examples reinforce Topics 1 and 4. By way of contrast, the four topics from the PC activity have much less in common conceptually.

If creativity shifts the balance of task ownership in the student's direction, and if they take advantage of this to the point of learning more, this doesn't necessarily mean they prefer such an approach. Isabella stated (and Sofia agreed) that she favors a teacher directed lesson over the wiki approach. She felt the best way to learn chemistry is to use the "real definitions and real examples". Ones the teacher would explicitly state. She preferred not having to use "soccer fields or the Harlem Shake" to explain chemistry concepts. Is it possible this aversion to the more open-ended wiki approach, might have benefits? It could be that a student like Isabella, by virtue of being "forced" to make sense of the concepts in a creative way, shifts her dissonance level from *perceived* low cognitive conflict (that is, believing she understood everything the teacher dished out) to a medium level inspired by having to push herself a bit.

Having the *student understand the goal* is the second fundamental characteristic of intersubjectivity. For our purposes, that will be taken to mean the "big picture" goal. For example, during the whole class introductory day lesson (i.e. what occurred in the regular classroom before moving to the computer lab), Jody described to all groups in all three activities the importance of wiki technology and how it facilitates collaboration. She noted it represented 21st century skills and commented "These are all things that frankly you'll have to do in the real world. It's going to happen to you beyond here so get

excited". She also mentioned various major companies, universities, and government agencies which use wikis. None of the results suggested a variance between activities in the extent to which students understood the activity goal.

Creating a *knowledge bridge* for students is the third and final means of establishing intersubjectivity. Just like the *combined task ownership* described above, the nature of the activity itself promotes knowledge bridge building. That is, by being asked to be creative, students are prompted to seek out connections between their existing cognitive framework and prospective knowledge. This includes cultural aspects of their cognitions. Similarities and differences in how this played out could be found when comparing the PC and CC groups. Regarding similarities, the teacher scaffolding for both groups was generally characterized by approval and encouragement for the students' creative ideas. As one example we haven't seen before, the following is the teacher's first discussion forum posting from Topic 3 of PC-1:

> First of all, I think the analogy to the taste of ice cream is great! I think making the point that the ice cream would taste basically the same if it was frozen or melted, and comparing this to how atoms are the same whether a solid, liquid, or gas, would be an excellent way to explain it to someone with limited chemistry background. This is the best part of the response so far because of its creativity.

As another example from PC, one we did see above in Topic 1b (Episode 4), the teacher feedback praised Valentina's example of two friends parting ways. At the same time, Jody offered revised support that encouraged group members to consider flaws in the analogy and "mention in what way this picture is NOT a good analogy for a substance changing into a gas". Similarly, the teacher feedback for CC groups was also encouraging and constructive. The teacher's discussion post for CC-4, Topic 4, noted "I also really like section 'c', especially the image. And the explanation is good to, but it

needs just a little bit of improvement". In other words, both PC and CC groups received

considerable encouragement regarding their creative efforts.

More revealing, however, are some subtle, isolated differences in how creativity

was fostered, and consequently, how knowledge bridge building was enabled. Very

likely without even being aware of it, the teacher offered CC groups greater unqualified

support for creative expression. Consider the exchange we've already seen between the

teacher and Santiago when he first introduces the idea of using the Harlem Shake as an

analogy for dissolved ionic compounds:

Santiago:	Should I put a Harlem Shake video in Miss?
Teacher:	How does that help?
Santiago:	I don't know cause there's like all settled and quiet and they're sitting down Miss and then they start going crazy.
Teacher:	OK. If you can explain that. Absolutely. It's your analogy, you can do whatever you want. You just have to be able to say why it works and maybe some reasons it doesn't.

The teacher's response here is unreserved. By asking "How does that help?", she

provides calibrated assistance in the form of ongoing assessment, but the tone of her

question is not judgmental. She reinforces this by stating, "It's your analogy, you can do

what you want". She does qualify that by asking Santiago to make sure he also explains

the shortcomings. This qualification comes *after* the unreserved encouragement,

however.

A similar exchange occurs during the whole class introduction. During the

brainstorming activity, as noted above, one unidentified student mentioned comparing

spectator ions to spectators at sporting events. This received unqualified teacher encouragement. However, since that analogy is the "industry standard" among chemistry teachers, that was expected. However the next student (also unidentified) mentions another group of individuals at the same sporting event:

Student: The announcers in the game.

Teacher: Why does that analogy work?

Student: Because the announcers aren't the ones that are in the game playing.

Teacher: They are just doing what?

Student: Watching it and talking about it.

Teacher: And are they there the whole time?

Student: Yes.

Teacher: Absolutely. That could be your analogy. So let's talk about a shortcoming of that analogy. How is that not [a good analogy]?

Again, note the teacher's initial reaction. "Why does that analogy work?" sends the message, in the positive tone it was delivered, "I'm interested. Tell me more". The caveat that it likely has shortcomings doesn't come until *after* the encouragement.

Examples from PC teacher-student interactions offer a contrast. During the PC introduction day, the teacher is brainstorming with the class about ways in which they can creatively explain that substances don't decompose when they change state into a gas (the misconception we discussed earlier in the complete sequence PC Topic 1a). Initially the students have no ideas; at least none they offer to verbalize. To catalyze the discussion, Jody then prompts them to "forget about the example of CO_2" and to consider

something from their everyday lives:

Teacher: So just think about a time like in our lives that where maybe we

                can see a change happening but the things involved in that change

                have not changed at all. So is there anything in your life that you

                can think of where there's maybe a group of something and it

                changes somehow.

                (Mateo is the first to summon the courage to raise his hand)

Teacher: Mateo.

Mateo: Like you and your friends, like if you guys were enemies and now

                your friends you're still the same person just now friends.

Teacher: Maybe, kind of, but. (Although I couldn't see his reaction, Mateo

                must have made a face of disappointment at this point, turned off

                by her less than enthusiastic response. She noticed his reaction and

                then tried to change the tone to a more positive one.)

Teacher: No, no, Mateo. I want to go from there. If it's you and one friend

                that's hard to imagine. Let's say it's you and a group of friends.

When Mateo first made his suggestion, the teacher might have initially imagined Mateo's

analogy as him with one friend. Having a firm understanding of molecular level

chemistry, she immediately recognizes that a more accurate analogy would involve

multiple friends, just like any sample of a compound has many molecules, not just two.

She even follows this up with an excellent analogy of a marching band that spreads out

and moves around, but in the end "It's still the same band…just in a different form". The

evidence suggests, however, this is all lost on Mateo. In spite of additional attempts to

engage him, and build off his creativity, his only response for the remainder of the discussion is a curt "OK" or "mmmm", like one does when feigning interest. He apparently was put off by the teacher's initial response (he did not show up for his focus group so it was not possible to confirm this).

Another interaction in which scaffolding to support knowledge bridge building was less than ideal for PC groups involved Luciana, and her initial topic that dealt with molecular level representations of elements, compounds, and mixtures (Topic 4). She had initially posted images of various assortments of jelly beans to represent the differences between elements, compounds, and mixtures. A container of only orange jelly beans to represent an element, a jar of black and white jelly beans to represent a compound, and a jar of many assorted jelly beans to represent a mixture. It was a good effort and the teacher acknowledged this in her discussion posting. At the same time, she suggested reconsidering using black and white jelly beans to represent a compound, because, if the jar of many assorted jelly beans represents a mixture, a jar of black and white assorted jelly beans would seemingly also represent a mixture and not a compound (albeit a mixture with only two substances, instead of many, but a mixture nonetheless).

During the midpoint day small group meeting, Luciana read the feedback and begrudgingly took it to heart. That is, she later said in the focus group that what she had initially, she thought, was "a pretty good example". In spite of this, she made a concerted effort to come up with new ideas on the spot. Revised analogies she suggested involved chocolate chip cookies, M&M cookies, macaroni and cheese, and flowers. The following interaction with the teacher involves the last in that group:

Luciana: (to the teacher) For a compound, could I say like um, like a garden

> of roses, red roses because if you think about it the stem and the
>
> rose are connected and they're, but they're two different things but
>
> its repeated over and over again.

Teacher: (pausing to think before responding) I think you could, I don't

think there is anything wrong with saying that, but you'd have to

explain very clearly. But like you don't really ever find stems and

flowers separately from each other (inaudible brief conclusion).

Luciana: (inaudible brief comment) I can't think of anything else.

In this case, the teacher's response "I think you could" was done in a tone that conveyed

skepticism. This interpretation is confirmed when Jody completes her statement, "But

like you don't really ever find stems and flowers separately from each other". Thus, like

the Mateo example above, the message is one of qualified support. The point here is not

that these are examples of a teacher being unsupportive. Quite to the contrary, she was

pushing the students to improve their ideas, as a skillful teacher should. The point is,

when it comes to encouraging creativity, so as to promote building bridges between

current and prospective knowledge, it is possible students may shut down if creativity is

critiqued *too soon*. Consider the following dialogue, regarding the flower analogy, from

Luciana's focus group:

Luciana: Yeah but she said that wasn't okay because she ended up saying

that wasn't okay because it's not one thing.

EO: And is that what you took from that? Because the way that she did

describe it was that "you know, that's OK, but make sure to

describe the shortcomings of it". But what you took from it was

that well, that must be wrong. (Luciana laughs)

EO: I don't mean to put words in your mouth.

Luciana: No, but you're right.

Thus, examples of intersubjectivity took shape in their relation to *combined task ownership*, *students understanding the goal*, and *knowledge bridges*. Combined task ownership was facilitated by encouraging student creativity. We saw an example of a CC student, Isabella, who may have been pushed from low to medium levels of cognitive conflict as a result of being compelled to be creative, even though she would prefer not to. This is emphasized not to highlight a difference among groups, but rather a scenario that might generate medium cognitive conflict generally. We saw no apparent difference among the groups for students understanding the activity goal. Finally, in addition to shifting the balance of task ownership to the students, encouraging creativity also helped students create bridges between current and prospective knowledge. This was a feature for both PC and CC groups. However, the scaffolding that promoted this bridge building might have been less qualified and more effective for the CC groups.

Having discussed intersubjectivity we will now turn to the second of three major characteristics of scaffolding. That is, calibrated assistance. Here, again, we will try to elucidate any differences between PC and CC groups.

Calibrated assistance. Calibrated assistance was described in the literature review as comprising two major characteristics. First, it entails *ongoing assessment*. Second, the ongoing assessment is often followed by *revised support*. Therefore, the following results are categorized according to these two major themes. Further, as with the intersubjectivity section, results are also described with an eye toward distinguishing

between PC and CC activities. We begin by describing examples of *ongoing assessment*.

For *ongoing assessment*, many similarities existed between the two activities. For both PC and CC, for example, the ongoing assessment generally took one of two forms: content assessment (How well do group members understand the content?) or motivational assessment (How much effort are the group members giving?).   More frequently it was content assessment. Two members of CC-2 highlighted this in their focus group. Sofia suggested, "[the activity] gives you information (inaudible) what group members are doing with their topic so you could try to help them". This ability to provide peer assessment was echoed by Santiago, "I just like the fact that you can see what your partner's doing and you can see the progress they are making". As he implies, this peer review can occur at any time, from any location. One group member can access the site, independent of others, and assess what others have been doing.

Peer ongoing assessment could also occur face-to-face. Recall earlier we saw Sofia and Isabella assess Santiago's comment about whether or not he should alter his description of the diagram representing the solid (line 15 and 16 of Episode 6 in CC-2, Topic 1a). The two girls immediately evaluate his current text and simultaneously say "No, no", as in "No, don't change it. It's correct the way it is". Another example occurred when PC-1 members, during the midpoint day, were discussing what Valentina (who was absent) had posted:

Luciana:	Which one did she say accurately shows sublimation [*sic*]?
Mariana:	This one. (probably pointing to #3)
Luciana:	Yeah, but which one did she say.
Mariana:	Three.

Luciana: She said three? I don't know if that's right or not.

Mariana: I was thinking four.

Here, Mariana is assessing Valentina's content and expressing second thoughts about it's accuracy.

Luciana's statement, "I don't know if that's right or not", demonstrates one of the advantages of teacher scaffolding noted in the literature review. That is, the teacher, unlike Luciana here, is generally a content expert who can immediately recognize the degree of accuracy of a student response. Instances of the teacher providing ongoing assessment were relatively consistent in both activities. Just as students can look into pages and monitor progress, so to can the teacher. In the teacher interview, Jody highlighted the benefits of this monitoring ability. She said, "It helps me see what they have and their explanation and to see what their conceptual understanding is".

This "peeking in" feature allows for prompt feedback that can be posted on the discussion board. For CC-4, Topic 1, Jody was able to post, "Section 'a' is correct. The answer is #2 and your explanation is pretty good…But work together with your group to improve that sentence", as a way of indicating her assessment determined their explanation was on the right track, but still in need of revisions. As a result of conveniently reviewing a wiki page for content, it also allows the teacher to spot plagiarism in a timely manner. A discussion posting from Jody followed such a revelation regarding CC-4, Topic 2:

> For section "b", please try again. It's ok if you go to websites to get information. But you can't just copy verbatim. You need to paraphrase what you read and put it in your own words! Also, remember to put the source of your images.

Most ongoing content assessment for both PC and CC, dealing with plagiarized content

or not, was done by the teacher in the form of reviewing the wiki content shortly before each of the two discussion forum postings.

On the other hand, the ratio of teacher to peer ongoing assessment was not as great when it came to motivational assessment. The teacher was still the one most likely to evaluate effort. Conscientious group members, however, did the same. For example, the fact that Gabriela from PC-2 was keeping tabs on her group member's progress was evident. She emailed them the night before the midpoint discussion. The following day she asks the others if they had gotten her email and jokingly gives Victoria a hard time about not having done anything yet. When asked during the focus group, Gabriela confirmed the email was meant to motivate her team. Victoria claimed she didn't read the email. Lucas, however, indicated it pushed him to get going. This contention is supported by the wiki history. He put most of his pre-midpoint content on his page at 9:43 PM the night before the midpoint. Jody suggested during the PC teacher interview this peer motivational scaffolding was not uncommon. She said those who were not "self-starters really rely on their group to get them going" and, regarding her observations of the midpoint small group interactions, "I just saw students making other students work".

As suggested above, ongoing motivational assessment more frequently originated from the teacher. As with content assessment, this generally took the form of reviewing wiki pages before each of the two teacher feedback posts. There were not infrequent instances where teams had added little or nothing to a particular page, even when deadlines had past. As a result of this assessment, the teacher would then post a message such as this one to PC-2, "Hey team! We need to get going on this! Let me know if you

need my help!", or this similar comment to CC-2, "For section 'b', you need to get going on this! Work with group members if you are completely unsure where to start. Let me know if you have any questions". There were no discernible differences in the amount or quality of motivational assessments employed by the teacher between the activities.

Were there *any* notable differences between PC and CC groups regarding ongoing assessment? That question is best answered by discussing what was not done, rather than what did happen. Three examples will be offered to suggest that additional calibrated assistance, in the form of ongoing assessment, would have been useful for the PC activity. The first deals with students who missed the wiki introduction day at the start of the school year. This refers to the day I introduced Wikispaces and use its tools (how to embed a video, edit text, add a message to the discussion board, etc…). Recall earlier, Luciana from PC-1 commented she felt behind from the start because she missed that presentation. I failed to collect attendance records from that day so I do not know who was absent. No evidence from the CC focus groups suggests a dilemma similar to Luciana's, however. That attendance that day was important was emphasized by Tomas from CC-4, who commented that being present made wiki usage "straightforward". Six months after the fact, he even recalled the terminology I used when I compared it to using Microsoft Word. Therefore, additional teacher ongoing assessment to ascertain wiki technical ability might have helped all students, and perhaps more so the PC groups.

Second, as was described earlier when summarizing the PC-1 complete sequences, additional ongoing assessments dealing with student focus would likely have proven fruitful, for the PC groups in particular. Recall, members of PC-1 had a lively discussion about the dry ice video. They never, however, discussed the primary topic, the

misconception that substances do not decompose when undergoing a phase change to a gas. One or two strategic questions from the teacher, at the right moment, might have been able to redirect them. As a point of contrast, the CC-2 group members we heard from in their complete sequences all demonstrated, to varying degrees to be sure, a focus on the topic at hand.

Third, ongoing assessment from the teacher, or even from a peer, might have aided students like Gabriela from PC-2. More than once, Gabriela expressed a comment that suggested she was overwhelmed by the *amount* of content. As one example, consider her remark at the end of the following. It starts with her reading, during the midpoint day, from the teacher's discussion posting:

> For conservation of mass, first consider your answer to whether or not there was conservation of atoms. *If* you decided there was same the same number and type of atoms as a liquid, as in a gas, then since the mass of a nitrogen atom is. "Oh, I feel like I'm gonna (inaudible) right here."

She then continued to read from the lengthy posting. About halfway through, she adds, "I need a break". After finishing the reading, she exclaims, "Oh my Jesus!". When asked during the focus group if she was feeling overwhelmed, she replied, "I was. I was. Because I wasn't taking it one step at a time". This demonstrates that even for a highly motivated student, feedback overload can occur. This example is meant to highlight that additional ongoing assessment might have revealed Gabriela's struggles. In this particular case, that would have had to have come from the teacher because Gabriela's group members were listening to her, and were in a position to provide scaffolding, but they failed to do so. We see, then, that calibrated assistance in the form of one of its characteristics, *ongoing assessment*, was perhaps most notable for when it wasn't employed, rather than when it was.

The second aspect of calibrated assistance is *revised support*. The focus now will be on the support that often follows ongoing assessment. For our purposes, however, that link did not need to be explicit. That is, once an activity was underway, any form of assistance was considered revised support. The assumption is the learning needs of each student are dynamic. This section will begin by highlighting the similarities between activities. It will conclude, however, by focusing on divergence. Thus, the results will be framed, once again, in order to facilitate a comparison between PC and CC groups.

We will begin with examples of revised support provided by the *teacher*. The most conspicuous form of this came from discussion forum posts, once just before the midpoint face-to-face, and once a few days before the final project deadline. For example, Mariana's description on her original topic, "When the atoms of water are in a gas form, they are really separated from each other" was correct in spirit, but not revealing enough to demonstrate the PC-1 member understood what she wrote. Hence, after reviewing Mariana's content, Jody wrote the following revised support in the discussion forum:

> So consider rephrasing this section slightly to emphasize that, yes, it's true that the atoms move farther apart in something like water as you go from solid to liquid to gas, but only because each molecule (which is made of the atoms!) moves farther apart from each other.

Jody also complemented Mateo from PC-2. For Topic 1b, he had provided an excellent example of how one can demonstrate water doesn't really disappear when it changes from liquid to gas. That is, he noted that placing a flat surface above boiling water promotes condensation on the surface. However, other parts of his explanation needed work, so Jody wrote:

> I think it's a great way to demonstrate that when water boils, the vapor doesn't

really disappear, even though it may seem that way. But your explanations do need some improvement, however.

She then was referring to his Topic 1a response and she goes on to ask him to clarify what he meant by "oxygen must always be paired". Such a point is critical, because the misconception being addressed relates to the perceived decomposition of substances as they change into a gas. That is, if one oxygen is *always* paired with another oxygen (which, of course, it's not), that certainly would have implications for whether or not it would decompose.

Teacher discussion forum revised support for CC was similar. The teacher compliments Diego from CC-4, "I really like section 'c'. Especially the image. And the explanation is good to…", but then goes on to redirect the group to consider revising by adding clarity to his description of spectator ions:

> So, I wouldn't get rid of this image and your general explanation. It's pretty good. But discuss it with your group and see if you can come up with a slightly better way to explain it so it's like spectator ions (i.e. they are independent ions in solution before and after the reaction).

CC-2 received similar discussion board revised support from the teacher. Recall the earlier example, described in Episode 8 of the Topic 1b complete sequence. The teacher tries to get the group to focus, with a fill-in-the-blank, on the fact that it is *ionic* compounds in particular that completely separate when dissolved:

> It is not always the case that just because something is aqueous, it totally separates (for example, sugar easily becomes aqueous, but it does NOT separate when dissolved). So just change your sentence a bit by filling in the blank "Also when (blank) is aqueous it means that it's totally separated". What goes in the blank (hint: it's a specific type of compound)?

These examples of teacher revised support are typical of what both PC and CC groups received in the discussion forums. The most significant deviation from that model would

be when a group had little or no content on a particular page. In that case, a short posting

such as, "Hey team! We need to get going on this! Let me know if you need my help!"

We saw comments like this introduced a short while ago as a response to ongoing

motivational assessment.

The teacher also provided revised support during the face-to-face small group

discussions in the computer lab. In this case, however, there was a noticeable difference

between activities. For PC, the revised teacher support was often on procedural matters,

rather than on content, such as how many points a particular section of the rubric was

worth, or how to access the teacher's discussion forum feedback. This was by

circumstance, of course, not by design. Consider this example from PC-2, which is

representative:

Teacher:	So you're reading through. Do you know how to look at my feedback?
Student:	No.
Teacher:	Click. If you click on here. There should be something titled feedback and then if you click it, it says what I thought, so things to fix.

For PC, the examples of revised teacher support that were more content focused were

limited, and their outcomes generally unsatisfactory. One such example we've seen

before, when the teacher scaffolded Luciana about her jelly bean analogy, as well as her

attempts at revisions. In that instance, Luciana made no corrections for the remainder of

the activity.

As another PC example, the teacher scaffolding likely contributed to the

revelation of an unexpected student misconception. During the midpoint day, Gabriela

from PC-2 was struggling to understand the Topic 2 teacher feedback. To help her

interpret the diagrams representing liquid and gaseous nitrogen, Jody commented that she

should focus on "how much space…is between the atoms and the molecules". This

represents just a small segment of a longer, more detailed explanation dealing with

conservation of matter in physical changes. Nevertheless, Gabriela seemed to focus

primarily on the "space" between the molecules. As a result, she adds to her wiki page,

"There is more oxygen in the gaseous nitrogen than the liquid nitrogen". She believed

the space between the nitrogen molecules contained oxygen, even though the description

on the page indicated it was nitrogen in the sealed container and there was no mention of

oxygen whatsoever. In an attempt to correct this, the teacher offered revised support in

her second discussion forum post. In spite of this, Gabriela clung to her misconception.

She did add additional sentences, but neglected to remove her "more oxygen" error and it

remained on the final version of the page.   Once again, this represents a less than ideal

outcome resulting from revised support in the PC activity.

By contrast, teacher revised support during midpoint discussion for CC was not

only more content focused, but generally also produced better results. Jody helped

Isabella from CC-2 formulate her understandings about Topic 3; dealing with the

misconception that conservation of mass does not occur in chemical changes:

Teacher:	The amount of mass you have in the beginning should be the same as what?
Isabella:	As the result at the end.
Teacher:	As the result at the end, because what did you do with those

atoms?

Isabella: Aren't you just combining them but the total mass number just gets

moved (note: She said "combining" not "recombining"; but the

teacher in next line says "recombining")

Teacher: Yep, you're just recombining them so your mass is also there; it's

just maybe organized in a different way.

As another example of content oriented revised support, consider the following brief

interaction between the teacher and a CC-4 member. Camila doesn't know the meaning

of the key word from Topic 2:

Camila: Miss, what's a lattice? (she pronounces it incorrectly,"latik")

Teacher: Lattice. That's a word you should look up.

Camila then searched for the word on Google, initially not finding it because of a

misspelling until a fellow group member corrected her. The concise response the teacher

provided to Camila's question should not be taken as a dismissal. Rather, it was a

considered response intended to shift the burden to the students. It reflected the teacher's

intentional effort to promote additional collaboration in the CC activity, as she described

in the teacher interview:

> So I really tried, especially for this third one to say ask your group members. See
> if someone in your group can explain it to you. Because I felt like no matter what
> I did I was either going to give it away or not provide enough help so I was glad
> to be able to say this was a collaborative project ask your peers.[17]

We will see soon below that what followed this Google search was one of the better

instances of peer revised support, ultimately providing an excellent example of effective

---

[17] Jody's decision for the third and final activity, Chemical Changes, to more often encourage students to "ask your group members" was hers alone. We never discussed beforehand making such a change in pedagogy. This reflects the quasi-natural element of the study.

distributed scaffolding (teacher, peer, and computer). I will now consider peer revised support.

Regarding *peer* revised support, focus group data revealed students from both activities were generally open to receiving revised support during face-to-face interactions. PC-2 member Victoria noted, "I liked how our group members would correct us and from there I will learn, say, I will remember on a test what my friend said from my group". When asked what situations in which assistance from another student was particularly helpful, fellow PC-2 member Lucas noted, "When she had us edit each other's problems, or whatever, we would just sit there and help each other. We would go one by one so we could understand it". CC-2 member Isabella said about the wiki activity in general, "I found it to be very interesting because you work in groups and you get to help people in the group".   It's important to emphasize here that Victoria, Lucas, and Isabella are all referring to peer support that originated during a *face-to-face* interaction. Recall earlier it was noted the students generally had considerable reservations about wiki peer editing. Here, however, we see a different tone when it pertains to face-to-face interactions. Therefore, this suggests part of the value added by the technology might be as a tool that facilitates face-to-face collaboration.

Instances of peers providing revised support in the PC activity included both procedural and content assistance. In PC-2, Lucas requested procedural help from Gabriela on how to post a video:

Lucas: How do you add a video?

Gabriela: Just copy that. (she must have been directing him to copy the
                   "Embed html" code from YouTube)

Gabriela:	Yeah.
Gabriela:	But don't paste (inaudible) go to your (inaudible). And then go to edit.
Gabriela:	And then go to Widget. And then to video, and then YouTube, and then paste it.

Gabriela's instructions were perfect and the wiki history indicates Lucas successfully uploaded his video. In another example of peer revised support, this one focused on content, both Luciana and Mariana from PC-1 are trying to make sense of the teacher feedback in the discussion forum. The issue is Topic 4, and whether or not the molecular level representations of #6 and #7 represent an element or a compound. Luciana, of whom it was her original topic, reads the teacher's feedback, "That's a tricky one because two atoms are bonded together in each molecule. This would be a compound…". At this point Mariana interrupts before Luciana can complete the sentence:

Mariana:	Wouldn't it be an element because they're the same thing. They're not?
Luciana:	Yeah, but I guessed they're a compound because it's two different ones.
Mariana:	She said those would be a compound *if* those two atoms were different elements.

Here, Mariana offers peer revised support by clarifying for Luciana what the teacher had written (never mind that she didn't give Luciana a chance to finish reading it in the first place). This also provides a good example of distributed scaffolding (teacher and peer), but, as we will see shortly, this same scenario had a less than ideal outcome.

Peer revised support was also apparent in CC. The first example is a continuation of what was introduced several paragraphs ago and is also a good example of distributed scaffolding (teacher, peer, and computer). After looking up the meaning of "lattice" on the web, as prompted by the teacher, members of CC-4 led by Camila and Samuel collaborate on how to describe Topic 2. Camila initially asks Samuel for help. After reading the current content on the page (which was posted by Camila before the midpoint discussion), Samuel verbally takes a stab at revising as Camila listens and types:

Samuel: A precipitate isn't a molecular (Camila heard typing) pairs of ions because they are not in pairs. (typing continues)

Camila: Molecular type of what?

Samuel: Ions.

Camila: Type of ions (inaudible).

Camila: Just keep it there.

Camila: OK, molecular type of ions.

Samuel: Because the molecular type of ions are in pairs.

Camila: Are in what?

Samuel: Are in pairs. (Camila continues to type)

Samuel: And the precipitate.

Camila: Because molecular types of ions are in pairs.

Samuel: And the precipitate isn't. (Camila types)

That this exchange was beneficial to Camila was specifically noted by her in the focus group:

EO: So you think the best part of it was you could get help from your

fellow group members?

Camila: Yeah.

…

EO: And do remember what was it specifically that they were able to help

            you out with.

Camila: I didn't get the word "latonic".

EO: What's that?

Camila: Latonic. The word.

EO: Lattice?

Camila: Sorry lattice. I didn't know what that meant so I didn't I didn't know

            how to solve it. So they explained to me that whenever you put it in

            water it would still stay the same even though it's adjusting to the

            other chemicals.

Camila's final thought "whenever you put it in water it would still stay the same" is a bit

ambiguous. Perhaps she means precipitates exist as lattices, just as they do when they are

solids *not* in water. In any event, she expresses an appreciation for the peer revised

support she received. Furthermore, it appears other group members were silent, yet

engaged participants. Diego noted in his focus group that it was Samuel who "searched

[the word 'lattice'] and kind of break it down [*sic*], break down the vocab and we

understand the question better". Also, note again, how students are generally open to

face-to-face support and edits which are discussed in real time, much more so than those

done online, asynchronously.

      Additional instances of peer revised support was demonstrated in the CC-2

complete sequences, such as when Sofia and Isabella corrected Santiago when he suggested changing his explanation of the solid in #1 (line 15 and 16, Episode 6, Topic 1a). Furthermore, Sofia and Isabella stated in their focus group they used multiple means of communicating to share ideas and give each other feedback. This peer support included texting, as described by Isabella, "Well, me and her like we have our numbers so when she would want help with the wiki we would just text each other and she would just ask me for ideas for creativity like pictures and the web". Thus, both PC and CC groups exhibited calibrated assistance in the form of peer revised support. As noted above in one of the PC examples, however, seemingly effective scaffolding does not ensure the learner on the receiving end will act on the support. Details on this will be described shortly.

The third form of distributed scaffolding is *computer-based*. For this study, this is taken to mean any computer based support that does not require dynamic input from another individual. This could include searching Google or another search engine for definitions or images, or using the Help links on the wiki pages. No notable differences were found between the PC and CC activities. When asked if they ever used the Help links, some members from PC-1 laughed as if to suggest they definitely hadn't. Mariana, on the other hand, also from PC-1, stated she did and that what she found helpful was "How to put pictures because I was like having a little bit of trouble with that, then putting a video up". Tomas from CC-4 also suggested he used the Help links, although he was vague on which link in particular.

Regarding search engines, many students utilized them to find images and content. In some cases, the search engine was a tool augmented by other support. For

example, we've already seen how the teacher provided revised support to Isabella

regarding conservation of mass in chemical reactions. Isabella, from CC-2, explains how

this was an example of computer and teacher distributed scaffolding:

> I first looked it up online and it wasn't really helping me and I asked [the teacher] and she explained to me that even though you put the chemicals together the mass stays the same throughout the whole equation so she helped me with that.

In general, Help links were used sporadically, with students preferentially opting to rely

on peer support to remind them how to post an image or video, such as we saw earlier

with Gabriela assisting Lucas. Use of search engines, on the other hand, was frequent.

We have now seen how both PC and CC groups received a fair amount of revised

support in the form of teacher, peer, and computer scaffolding. At times it led to the

desired outcome. There were instances however, some of which were alluded to above,

in which the scaffolding itself, or the outcome, was less than ideal. Consider that, at

times, perhaps the teacher discussion forum posting did not encourage enough reflection

or greater collaboration[18]. This might be especially problematic if it occurred as part of

the first discussion posting, the one just before the midpoint, when students still had

roughly one week to complete the project.

Consider the case of PC-1 Topic 4, in which students had to identify molecular

level diagrams as an element, compound or mixture. Luciana had correctly labeled #3 as

a compound. Her explanation was poor, however, because she was referring to the H_2S

unit as an atom, rather than a molecule. Rather than suggesting the group discuss more

appropriate phrasing, something they would certainly have time to do during the

---

[18] Recall, I was the one who originally composed the teacher feedback for the discussion forum. The degree to which Jody proofread them is not known. Changes she made were very minimal, and were limited to peripheral comments, such as the "Let me know if you need any help!" added to the end of the post.

midpoint face-to-face and the week that followed, the teacher feedback explicitly stated

the correct phrasing, "#3 is correctly labeled a compound, but the explanation should read

'because they are all the same type of molecule, each molecule having one sulfur atom

and two hydrogen atoms'". During the midpoint day, Luciana and Mariana spend

considerable time discussing that topic. When they get to #3, however, the only item

they correct is a grammar issue (see Figure 18), by deleting an unnecessary word, "on".

Perhaps a rephrased teacher posting would have prompted them to reflect more. The pair

completely ignores the conceptual issues which need to be resolved, such as strategically

changing the word "atom" to "molecule" as the teacher suggested.

Figure 18

Grammar-only correction for PC-1 on Topic 4

1. Number 1 is a compound. It is a compound because it has a chlorine atom, a hydrogen atom, and an oxygen atom attached together, but repeatedly.
2. The second one is a an element because it is just single helium atoms.
3. The third on box is a compound because they are all the same atom, but the atom is a mixture of a sulfur atom and a hydrogen atom.

The reason they hadn't made a more substantive change initially is revealed,

perhaps, by the midpoint day dialogue with the teacher. Jody asked, "Do you guys know

how to check the feedback I gave?". More than one student said "No". The teacher then

reminded them where to find it. Therefore, when they made the initial grammar change,

perhaps they hadn't read the teacher's revised support yet. They then still had another 20

minutes, however, to make the conceptual change, and they never did. It wasn't until two

days later, that Mariana, presumably working independently at 6:04 PM, made the

correction. In any event, the main point here is that the teacher scaffolding in the

discussion posting did not encourage discussion and reflection. To the extent that it may

not have mattered for this group, it might have for others.

For example, a similar scenario of the teacher feedback not encouraging reflection and collaboration was also demonstrated for PC-2, ironically also for Topic 4. It was a similar issue in that Lucas had correctly chosen "element" as the answer for #6 and #7, but his explanation had shortcomings. To help the student rectify this, the teacher posted the following revised support, "Containers #6 and #7 are correct. But for your explanation, instead of saying 'because it is only one atom' you really mean to write 'because there is only one type of atom'". The outcome was again less than ideal. As a contrast to the PC-1 scenario, this group does make the correction during the midpoint. However, the evidence suggests it is a unilateral, not collaborative edit. Gabriela, who had dominated the discussion, reads the teacher feedback and directs a comment, likely toward Lucas, "OK, so six and seven is going to be really easy. I can do it for you because it's really easy". She then says "same type of atom" as she types the correction (see Figure 19).

Figure 19

Unilateral correction for PC-1 Topic 4

Container #7: I would classify container 7 as an element as well because it is only one the same type of atom.

She concludes by saying "OK, that was easy" while the two other group members present, Lucas and Victoria, can be heard with muted chuckles (the fourth member of the group, Mateo, was absent for the midpoint). Because the teacher posting explicitly told the group what to write, it is difficult to know if even the most active member, Gabriela, was "minds on" as she made the edit. It appears the other two members were probably not, having not contributed to either the dialogue or the typing, and no additional

evidence suggests otherwise. During the focus group, after being reminded of the scenario, Lucas and Victoria were asked if they were actively engaged when Gabriela made the changes. Neither could remember.

CC groups also had one or two instances in which the teacher feedback in the discussion forum was perhaps more explicit then it should have been. Recall earlier we saw in the second teacher posting for CC-2, Topic 1b (Episode 4) the comment:

> As for section "b", I like it! Great idea! If I were to be nitpicky, maybe you could just explain briefly that the Harlem Shake would be an even better representation of aqueous ionic compounds, like NaBr, if each soldier moved around more (i.e. didn't just "dance" in the same spot) just like each independent ion in a solution really floats all over the solution.

In this case, the group is not encouraged to discuss the remaining shortcomings of their analogy. The teacher feedback simply spells out that it would be a better representation if "each solider moved around more". Ultimately, without the input of his group members, Santiago made an imperfect correction as described earlier (he exaggerated that the video *did* show soldiers "moving all around the place rather than dancing in one place").

The primary point here is not that there were major differences between PC and CC groups in terms of the degree to which the teacher feedback in the discussion forum encouraged reflection and discussion. To be sure, many instances of such teacher feedback, for both PC and CC groups, were written to encourage reflection and collaboration. This was demonstrated in many of the examples we've seen earlier, such as when PC-1 was encouraged to point out shortcomings of their analogy, "…but like most analogies, it seems to me it has at least one flaw. So please also mention in what way this picture is NOT a good analogy for a substance changing into a gas", or when CC-2 was asked to improve their explanation regarding aqueous ionic compounds, "…so

what is it about Diagram #2 that lets you know it represents an ionic substance dissolved in water. Hint: Focus on what it says in the first few sentences at the top of the page". The point is that perhaps by revealing too much of the correct answer upfront, it might limit students collaborative efforts and performance. If there is a slight difference between the PC and CC groups, it is that these potentially less than ideal forms of scaffolding appeared for the PC groups in the first teacher post (before the midpoint), and for the CC groups in the second. In other words, the PC groups might have benefitted more from the midpoint meeting face-to-face had they been encouraged to collaborate more beforehand.

Other instances existed, however, in which the revised support differences between the PC and CC groups was more observable. These events were infrequent. Nevertheless, there were three isolated and discernible events that reflected less than ideal scaffolding and/or outcomes for PC groups relative to CC. All three scenarios were described earlier. The first involves the teacher offering revised support to Luciana regarding her jelly bean analogy, as well as her subsequent attempts at revisions. In that case, it is possible the teacher feedback included seemingly appropriate, but ultimately untimely comments regarding the worthiness of Luciana's creativity. That is, had the message conveyed to the student been perceived as more constructive than critical, perhaps Luciana would have taken greater initiative to make changes. As it ended up, she made no changes whatsoever to what had started off as a good first attempt.

In the second scenario, recall that PC-2 member Gabriela was so overwhelmed by the sheer volume of revised support contained in the first teacher posting that she exclaimed, "Oh my Jesus!". During that same sequence, Gabriela later said "This is

giving me a headache". Triangulation of focus group and midpoint transcript data

confirmed her feelings of despair as she read the teacher's lengthy feedback. It was

apparent it was too much at once. It is important to note, however, that it was too much

for *her* at *that moment*. On a better day, perhaps it wouldn't have seemed so

overwhelming to her. Further, maybe for another student, the amount of feedback would

have been ideal, on any given day. For example, the posting Gabriela was reading had

444 words. By contrast, PC-1 members, for Topic 1, received 413 words of feedback in

the first teacher posting and 768 words in the second. That group, however, in spite of

the lengthy feedback, demonstrated an excellent response to the teacher's revised support

(recall that it was primarily Valentina making most of the changes dealing with her dry

ice video explanation, and her images of friends parting ways). The key point here is that

at the moment that led her to exclaim "Oh my Jesus!", it was too much for Gabriela, who

should have, as she noted later, taken it "one step at a time".

The third scenario in which there was a discernible difference between CC and

PC groups we've touched on earlier only very briefly, at the end of the PC-1 complete

sequence for Topic 1a. That group, who was clearly interested and engaged with the dry

ice video, had nonetheless failed to ever discuss the relevant misconception being

addressed. Well into the video, after making comments such as "That's cool!" and "Is it

that strong? Oh my God!", they flag down the teacher:

Luciana:	Did you see Valentina's video?
Teacher:	I looked at it briefly. Which one was it?
Students:	[The one with the dry ice.]
Teacher:	I didn't watch the whole thing because I had to get everyone's

done.

Jody appears to not have had time to fully review the wiki content before the midpoint meeting[19]. Unfortunately, what then transpired was a missed opportunity to redirect the students. That is, to channel their noticeable enthusiasm towards explaining why, when substances change state into a gas, they don't decompose. Thus, the three scenarios of revised support described here (critiquing creativity too soon, providing too much scaffolding at once, missed opportunity to redirect) all reflect isolated, yet discernible instances in which PC scaffolding differed from CC. The data for CC revealed no direct analog to the three PC scenarios just described.

That is not to say that the outcomes, for either activity, were generally ideal. Both PC and CC activities involved multiple instances of seemingly effective revised support that was not acted upon. We've seen the PC-1 example of Topic 4. In spite of the fact that Mariana suggested to Luciana the answer for diagram #6 should be "element" instead of compound, and despite the fact that both teacher posts indicated that "compound" was incorrect, the error remained in the end. In this case, on its face, the distributed scaffolding (teacher and peer) should have been effective. It apparently wasn't, at least if one considers that external wiki knowledge represents an individual's internal cognitions. As noted earlier, Luciana's focus group comment, "that's just me being a slacker", might be the best explanation for her personal lack of effort.

Luciana opined further, however, her feelings about getting assistance from group members, "I think maybe just like if I had a hard topic I would ask them, and they

---

[19] It's worth repeating at this point that Jody, in addition to teaching full-time in only her second year of teaching, was also taking two graduate level courses in pursuit of a Master's degree. The particular incident being described here occurred in early December, perhaps the same time final assignments were coming due for her own coursework.

wouldn't really help me. I think they would try but I wouldn't get it. I think it would just be better to ask the teacher". She hints that the suggestion by Mariana that "element" was the correct choice is greeted with initial skepticism. Ultimate knowledge, and the final word, is deferred to the expert, the teacher. Luciana is not the only student with this opinion, as the teacher suggested:

> I feel like my students are still really skeptical at the whole idea that they can help each other and I don't know where that comes from. Why they feel like they can't help each other with things. I see that all the time. It's not just with the wiki project. Like when we were studying for our test we had eight students who met me to study for this test before we had it, and I said "Ok you understand this, why don't you explain this to her", and they were like, "Oh, are you sure, you're the teacher?" It's just the idea that they're not the most knowledge so therefore they shouldn't be trying to teach other people.

The issue of being skeptical about giving or receiving assistance from your peers notwithstanding, it still doesn't explain why Luciana or others in her group didn't heed the teacher's suggestions in the discussion posts to make the corrections. During the focus group, other PC-1 members suggested they never saw the teacher's comments, even though one of them "went back twice" to review the posting.

That PC example was not the only one in which revised support was not acted on. For that matter, similar inactivity was demonstrated by CC groups. This primarily pertained to CC-4. For Topic 1, for example, the first teacher post noted:

> But I was not crazy about your remark that #3 is like a mixture. Why did you think that? Discuss this with your group what might be a better way to describe #3. If you have any questions let me know. A hint: #1 is a realistic picture of a solid ionic compound in water. #2 is a realistic picture of a dissolved ionic compound in water. #3 could not be an ionic compound in water, however. Why not?

In spite of the hint, the explanation was never revised. The teacher posting for Topic 2 also contained a hint in the form of a fill-in-the-blank, "…What would be a better word to

use instead of molecules? Hint: The particles in ionic compounds are not molecules, but charged particles called (blank). Fill in the blank". This too, was never corrected. That being said, the prevalence of not taking action based on revised support was greater in PC, to the extent that their inactivity prompted the teacher to extend the final deadline for them to complete the project. Jody lamented about this in her interview:

> …we moved the final deadline and I really thought that they would take that more seriously…I said I'm giving you this extra chance…Here's this extra opportunity to get it done and I just didn't feel like, given where they were at, I expected a lot to happen overnight. I expected exponential amounts of edits and I was surprised [that didn't happen]…when I saw pretty much the same thing the next day I was like great. I know I've already said this but I can't explain why that would be.

When I asked Jody if she thought semester exams (the end of the PC activity was in mid-December, just before exams) were the cause of inactivity, she didn't think so. She even suggested the fact that grades would be assigned soon should have propelled them to perform better on their wiki, which was worth not an insignificant portion of the semester grade.

In the end, there were numerous examples of revised support for both PC and CC activities. Much of it was seemingly sound scaffolding. At times, however, shortcomings were apparent. This included more instances in which the PC groups experienced either scaffolding with inadequacies or, for other reasons, it led to less than ideal outcomes, such as not acting on feedback. For example, the PC group could have used additional ongoing assessment and revised support that would have redirected their focus to the primary objective of a particular page.

Now that we have seen examples of ongoing assessment and revised support, which together constitute calibrated assistance, we will now move to the third and final characteristic of scaffolding in general. That is, after intersubjectivity and calibrated

assistance, the remaining characteristic is *fading*.

    Fading. As noted in the literature review, some researchers suggest fading is the "defining characteristic of scaffolding that distinguishes it from other forms of support" (Wu, 2010, p. 26). The transfer of responsibility is passed along to the student gradually, in a non-abrupt manner (F. Wang & Hannafin, 2008). By this definition, fading was not apparent in either the PC or CC activities. Given the quasi-natural aspects of the study, and that fading in the strict sense is impractical in most classrooms, let alone in a high school class with 15 students trying to learn abstract concepts, this is not surprising. In the Discussion chapter we will return to the concept of fading. There, recommendations will be offered on how distributed scaffolding might alleviate, at least in part, this dilemma.

    Internet access survey. Responses to the Internet Access Survey (see Appendix Z for survey) indicated most students in PC and CC groups had home internet access. For PC, 13 (out of 16 respondents) reported they did. Of those 13 students, 7 reported some other issues that compromised this access, such as another family member using a shared computer, or a slow connection. For CC, 12 (out of 13 respondents) indicated they had home internet access. Of these 12, there were 9 who had other difficulties such as sharing with other family members, a computer that sometimes froze, and slow Wi-Fi attributed to multiple users at once. One CC student indicated the only home internet access was on a phone. These results indicate no obvious differences between groups that would explain different outcomes. They do suggest, however, that home internet access for educational purposes is certainly not as unhampered as is experienced in many middle or upper class homes where multiple family computers and high speed

connections are becoming ubiquitous.

In addition to home internet access, all students had access to computer labs on school days from 4:15 PM – 5:00 PM. The teacher noted this access is sometimes limited by their ability to find after school rides. In addition, most school mornings the computer lab was open from 8:00 AM – 8:30 AM. The teacher also made laptops available in her classroom during her chemistry tutoring time once a week, from 3:30 PM – 4:15 PM. Jody indicated there were a few students who took advantage of this, but not many.

Summary (Research Question 1). Hypothesis 1 asserted that, as measured by posttest scores, the academic achievement of the treatment (wiki) group would be greater than that of the control (normal instruction) group. For the overall analysis, this was not supported. However, for the chemical changes activity alone, the wiki group did significantly better than the normal instruction group. This was due, in large part, to a superior performance on two questions dealing with submicroscopic representations of precipitation reactions. The effect size for the difference in means for these two questions alone was very large (Cohen's $d = 1.33$). Furthermore, an association was demonstrated between group membership and the ability to overcome the misconception that aqueous ionic reactants exist as molecular pairs prior to being mixed. Wiki students were significantly better at overcoming the misconception.

Qualitative analysis revealed several factors illuminating the reasons for the non-significant result overall, and the anomalous results for CC. Perhaps the aversion to collaborative peer editing is the primary factor that led to the non-significant result overall. As for the disparate results between PC and CC groups, intersubjectivity may

have been established more effectively in the CC activity. Furthermore, the PC wiki

groups might have needed modified calibrated assistance with two adjustments. First,

support targeted at ensuring *all* group members were actively engaged in *all* topics.

Second, at several strategic points, PC groups needed redirection. That is, to get them

focused on primary rather the peripheral concepts. Finally, the exceptional performance

of the CC groups on the submicroscopic representations of precipitation reactions might

be attributed, in part, to the fact that three of the four topics had the same underlying

concept presented in different contexts. All of these issues will be unpacked in greater

detail in the Discussion chapter.

Research Question 2

Research Question 2: What are the characteristics of distributed metacognitive

scaffolding when Latino high school chemistry students

collaborate on a quasi-natural wiki project?

Hypothesis 2:   The teacher will be more effective than peers at facilitating

metacognitive thinking in learners.

The results for Research Question 2 differ in two ways from Research Question 1.

First, Research Question 2 is answered with only qualitative data. Second, the emphasis

here is on differences between teacher and peer scaffolding, rather than differences

between wiki and normal instruction groups.

As another introductory note, recall computer scaffolding also comprises one

possible means of distributed scaffolding (in addition to teacher and peer scaffolding).

Instances of this were generally limited to web searches, however, which *every* group did

as matter of course. Thus, rather than placed in its own section below, computer

scaffolding is introduced from time to time as appropriate among the teacher and peer results.

The two major themes of metacognitive scaffolding, for the purposes of this study, were *recognizing knowledge gaps* and *knowing what to do about it*. The three categories of the former were *content knowledge*, *general goals knowledge*, and *making connections knowledge*. The one and only category of the latter is *strategy knowledge*. Regardless of the category, it is important to emphasize three important generalizations about how data came to be categorized. The first is that it was considered metacognitive scaffolding, or an aspect thereof, if it was support intended to prompt students to reflect. Second, it was also considered metacognitive scaffolding, or an aspect thereof, if it was likely to prompt students to reflect, regardless of the intent. Third, the term "reflection" is broadly construed so it encompasses most instances that would involve thinking about the relevant knowledge, strategies, or goals.

Various emergent subcategories arose during analysis of the data. Each of the four major categories was divided into peer and teacher subcategories, which were than further characterized into emergent subcategories. For example, metacognitive scaffolding – content knowledge (MS-CK) was divided in peer subcategories of *wiki content*, *posing a question*, and *taking initiative*. Teacher MS-CK was divided into *posing a question*, *video explanation*, *sentence starters (fill-in-the-blank)*, and *look up definition*. Table 9 has the complete list of subcategories for each major category.

Recognizing Knowledge Gaps.

Metacognitive scaffolding - content knowledge (MS-CK). Both peers and teacher demonstrated an ability to stimulate reflections on content knowledge in others.

Table 9

Categories of Metacognitive Scaffolding

	Recognizing Knowledge Gaps			Knowing What to do About It
	MS-CK	MS-GGK	MS-MCK	MS-SK
Peer	-wiki content -posing a question -taking initiative	-rubric reflection	-creative connections -real-world connections	-increase effort
Teacher	-posing a question -video explanation -sentence starters (fill-in-the-blank) -look up definition	-rubric reflection -learning to collaborate	-creative connections -creative shortcomings -activity connections	-increase effort -trial run reflection

MS-CK = metacognitive scaffolding – content knowledge; MS-GGK = metacognitive scaffolding general goals knowledge; MS-MCK = metacognitive scaffolding – making connections knowledge; MS-SK = metacognitive scaffolding – strategy knowledge

There were fewer such instances for peers, however. Although several distinct means of peer scaffolding were identified, each was generally comprised of an isolated event or two, rather than multiple occurrences sharing a common theme (other than the theme of dealing with content knowledge). We will begin with examples of *peer* MS-CK. That will be followed by *teacher* MS-CK.

Peer MS-CK. First, there was the *wiki content* itself. That is, the content on a page posted by one student would prompt another student to reflect. For example, CC-2 member Isabella had added the following brief content to her original topic, "The total mass at the beginning doesn't change throughout the chemical equations, they are just being re-combined without being changed". Although it is highly unlikely her intent had anything to do with metacognitive scaffolding, Santiago recalls how it still prompted him to find a video that demonstrated conservation of mass:

Santiago:	I just like the fact that you can see what your partner's doing and you can see the progress they are making and you can edit and paste…I remember like if, I think it was one of my teammates, I posted a video [that related to] what they were doing.
EO:	OK, so just so I understand. One of your group members did something first.
Santiago:	Yeah. Then I was watched [*sic*] a video and like it was relating to what they had, so I posted it.

He eventually embedded an excellent video (see "Chemistry concepts: Conservation of mass/energy," 2009) that was the perfect complement to Isabella's text.

In his focus group, Santiago's further comments suggest a willingness to reflect on content posted by a group member:

> Well, I like that fact that you can, I think, edit where you can see who changed something and when they changed something. So you can see which teammate helped you and if you still don't understand why and you can ask them perhaps and they'll give you further explanation.

Furthermore, the tables were turned and one of Santiago's group members appeared to reflect based on his original content. Earlier in the complete sequences (Episode 5, CC-2, Topic 1a), we saw his original content edited by Sofia. That is, she made a minor but significant change by changing "grouped" to "paired" when referring to one of the counter examples. It appears that Santiago's original content played a role in getting her to reflect. Her edit channeled the text directly onto the misconception's focus. That is, it dealt with molecular "pairs" of ions rather than the more general "groups" of ions.

Another way in which a peer implemented MS-CK was by *posing a question* for a group member. In a scenario we've seen before, Mariana asks her PC-1 partner Luciana,

"Wouldn't it be an element because they're the same thing, they're not?", when referring to diagrams #6 and #7 in Topic 4. In this case, Mariana correctly suspects the answer is "element" and not "compound". Thus, her "question" is less a question, and more of a message to Luciana that she should reconsider her assertion that they are compounds. Luciana replies, "Yeah, but I guessed they're a compound because it's two different ones". Mariana then reminds Luciana about the teacher's posting that it would be a compound *if* the two atoms were different elements. The main point here is that Mariana's original question for Luciana was metacognitive in nature. Again, that's not to say it was intended that way, but it certainly had the potential. In the end, no corrections were made, possibly suggesting limited reflection on Luciana's part.

One group member simply *taking initiative* to lead the face-to-face discussion was another means by which MS-CK occurred. Consider the following PC-2 dialogue in which Gabriela clearly takes the lead as the group considers whether the images in Topic 4 are an element, compound or mixture:

Gabriela:	It's not a mixture (inaudible).
Gabriela:	Do you want to do it? Or we can all do it together?
Lucas:	So it's a compound.
Gabriela:	Yep, this would be a, this and this would be a mixture (probably pointing to 4 and 5)
Gabriela:	And that's an element, that's a compound, that's an element and that's a compound.
Lucas:	Why?

With his limited participation, it is uncertain that Lucas was reflecting at all on the

content described by Gabriela, who has taken the initiative to move the discussion

forward. Shortly thereafter, however, Lucas expands his contribution as they refer to the

first image:

> Gabriela: Because each atom has the same element, the same type of
>
>   element. No.
>
> Lucas: Chemicals.
>
> Gabriela: Because?
>
> Lucas: Chemical elements.
>
> Gabriela: The chemical what?
>
> Lucas: It's like consisting of two or more different chemical elements.

The pair is not quite there yet, but Lucas' description of "two or more different chemical

elements" suggests he is closer to understanding why the first diagram represents a

compound. It appears that as a result of Gabriela's aggressive approach to the

conversation, he has thoughtfully reflected.

Tied to the previous discussion is an instance, not described above, in which

Lucas took the opportunity to search Google for the definition of the word "compound".

Taken together with Gabriela's peer scaffolding, it represents a form of distributed

scaffolding (peer and computer). As further evidence that Lucas was engaged and

reflective, it was he who eventually made subsequent improvements. These include his

emphasis on the elemental composition (see Figure 20). As a point of clarity, his

comment about "…a compound because they have the same chemical elements…"

(Figure 20) is not inconsistent with his description above of "two or more different

elements". Based on his complete statement on the wiki page, he seems to understand

that compounds have different elements within the molecule, but the same elemental

composition when comparing one molecule to the next.

Figure 20

CC-4 Corrections Resulting from Distributed Scaffolding

Teacher MS-CK. Many more instances existed of teacher MS-CK compared to

peer. There was also more than one category in which multiple instances were found.

The first type of MS-CK was evident as a result of the teacher *posing a question.* This

occurred most commonly in the teacher posts, but also during face-to-face interactions.

In the first teacher post for PC-1, Topic 4, for example, the teacher wrote:

> #6 is incorrect. That's a tricky one because two atoms are bonded together in each
> molecule. This would be a compound IF those two atoms were DIFFERENT
> elements. But in this case they are not. So what do you think the correct answer
> is?

In another example (PC-1, Topic 2) the group is asked to clarify their understanding of

conservation of matter:

> First, was there conservation of atoms in the nitrogen change represented? You
> did say there was conservation of molecules above. Good, that is correct. Does
> that mean there was also conservation of atoms?...If you decide that answer to that
> is YES, then what does that tell you about mass? If atoms were conserved, was
> mass also conserved?

In both of the preceding examples, by posing a question, the teacher expects students to

reflect on their content knowledge. In the second example, the revisions were never

made. Steve, the experienced chemistry teacher who reviewed my qualitative coding,

agreed the teacher's question was metacognitive. However, he also noted the students

may have assumed that atoms and mass were conserved based on their comment that molecules were conserved. Perhaps for that reason, changes were never made.

In addition to several other instances in which posing a question was done via a teacher posting, it also occurred during the midpoint face-to-face meeting. We saw earlier in the complete sequences (Episode 6, CC-2, Topic 1a) the discussion between Jody and the group about how best to explain that ionic compounds are completely separated when dissolved. Immediately following that exchange, Jody suggested, "Separated…and there's another word for that" in response to Santiago, who suggested he use the word "separated" in his explanation. I am not certain what alternate word Jody was getting at. Nevertheless, it clearly seems to have had the effect of getting Sofia, who was paying attention, to reflect on it. Later, she asks Isabella, "How can you say this instead of saying its 'separate'?" Isabella replies, "Spread out". Shortly thereafter, Sofia adds the following to Topic 2 (italics added):

> The diagram that shows barium sulfate best is diagram one beacuse [sic] the definition of precipitate is when a solid forms. diagram [sic] one shows barium and sulfate are together in a solid form. Number two wouldn't work beacuse [sic] the chemicals are *spread out*. Number three wouldn't work either beacuse [sic] there [sic] in pairs, but there not all together [sic].

Thus, whatever the teacher's intent, it appears to have stimulated reflection on the relevant concept. Perhaps "spread out" is a more meaningful term than "separated" for Sofia and/or Isabella.

It is necessary here to briefly refer back to the results for the first research question. An assertion was made regarding CC wiki groups. That is, it was suggested their superior performance was due, in part, to the considerable overlap among the four CC topics, relative to the four PC topics. That is, the same underlying concept was

presented in different contexts. The preceding dialogue that led to "spread out" being offered as an alternative to "separate" supports this claim. The teacher's initial comment "Separated…and there's another word for that" was made in the context of a *Topic 1* conversation. However, Sofia's remark "How can you say this instead of saying its separate?", as well as her subsequent edit, deals with *Topic 2*. That is, the teacher scaffolding for one topic prompted student reflection that directly impacted their understanding of another topic.

Other examples of how the teacher provided MS-CK revolved around asking students to improve their *video explanation*. Several groups, in both PC and CC activities, embedded or linked one or more videos. Many of these had redeeming qualities related to the primary objective of a particular topic. However, most videos lacked an adequate student-generated written explanation that linked the content of the video to the primary objective. In other words, although the rubric called for an explanation to accompany images and videos, students often fell short on this standard. Therefore, the teacher posts were often used to call students attention to this dilemma. As one example of where the scaffolding yielded good results, consider first the teacher posting related to the PC-1 dry ice video, "The video is excellent and gives some very interesting demonstrations of the properties of dry ice. Just make sure to add a brief explanation that ties in the video with the overall topic". As described earlier, Valentina took the lead and made several additions that support the topic objective, especially her comment, "IF we could see the molecules, we would see particles of CO_2 going up." Here, her explanation demonstrates content reflection to the point of directly addressing the misconception that substances do not decompose when changing from solid to gas. Several other groups also received

teacher MS-CK to improve video explanations. In those instances, the teacher's comment was similar, but student follow through was generally deficient.

For both PC and CC activities, another form of teacher MS-CK was *sentence starters* (to use the term introduced in the literature review). Perhaps some of what follows, however, would be better classified as simply *fill-in the-blank*. Regardless of the nomenclature, some instances appear to have led to reflection on content, while others not as much. All fill-in-the-blanks were communicated in the discussion forum. For PC-1, Topic 4, the teacher wrote, "…#5 is also correctly labeled a mixture. But the explanation would be better described as "because it has a mixture of helium atoms and chlorine (what goes here?)". In spite of the explicit prompt "what goes here?", the group never made a correction. A similar comment was made to CC-4, on Topic 2:

> I like the way you described that #1 is the solid precipitate because the particles are "joined together". But you also say they are joined together "with the other molecules". What would be a better word to use instead of molecules? Hint: The particles in ionic compounds are not molecules, but charged particles called (blank). Fill in the blank.

This sentence starter, or fill-in-the-blank, was also never addressed. In discussing this scenario with Steve, he suggested this example of teacher scaffolding was less about metacognition and more about simple clarification.

Some MS-CK fill-in-the-blanks did seem to have greater, if imperfect, impact. Recall the following from CC-2, Topic 1a, that we saw in the complete sequences:

> However, it is not always the case that just because something is aqueous, it totally separates (for example, sugar easily becomes aqueous, but it does NOT separate when dissolved). So just change your sentence a bit by filling in the blank "Also when (blank) is aqueous it means that its totally separated". What goes in the blank (hint: it's a specific type of compound)?

In this case, Santiago did address the teacher's prompt. However, he completed the

sentence by filling in the blank with "NaBr" instead of the more general "ionic compounds" the teacher was looking for. Although technically not a fill-in-the-blank, a similar type of scaffolding occurred for CC-4, also Topic 1a:

> It is true that in the particular example of NaBr, it was the two elements that separated. But what if it had been a different ionic compound, like NH4Br. In that case it would have separated like this: NH4Br --> NH4+ + Br -. So it's not really all the elements that separate, but rather the two different what?

This too had a flawed correction. The group replaced "elements" with "compounds" instead of "ions". Steve suggested this MS-CK might have been expecting too much of the students. It required them to differentiate between polyatomic and monatomic ions without having it explicitly pointed out to them.

The final category of teacher MS-CK dealt with asking groups who were unsure of a term's meaning to first *look up definition*. This occurred in place of telling them the answer directly or even trying to talk them through it. Although the emphasis for the second research question is comparing teacher to peer scaffolding, and not PC to CC groups, there were only three discernible instances in which the teacher requested the students look up a definition, and they were all in CC. Furthermore, they all turned out successfully. As one example, consider the following midpoint dialogue between the teacher and Sofia and Isabella from CC-2. The girls were tackling Topic 2 and were uncertain of what the word "precipitate" meant. The teacher suggests they look through their text book to determine the meaning. She then follows up less than a minute later:

Teacher:	What did you learn?
Sofia:	A solid that forms in a precipitation reaction. (apparently reading from the book)
Teacher:	So the key to that is remember that's where we write out our

equation to predict our products. Is the precipitate a solid or is it aqueous?

Sofia: A solid. (said quietly)

Teacher: A solid. So it's something that's insoluble in water.

Sofia: So it would be number 1. (Isabella also says something inaudible)

Teacher: I would agree with that but I would want you to tell me why.

Shortly thereafter, Sofia shows evidence of having reflected on the meaning by adding the following content to the wiki, "The diagram that shows barium sulfate best is diagram one beacuse [*sic*] the definition of precipitate is when a solid forms. diagram [*sic*] one shows barium and sulfate are together in a solid form…". Two other scenarios occurred in which the teacher asked CC-2 and CC-4 members, respectively, to look up a definition. In both these examples the term was "lattice". In each case, what ensued was a relatively collaborative discussion as the groups tried to make sense of the meaning.

We have seen then, examples of metacognitive scaffolding for content knowledge (MS-CK) demonstrated by both peers and teacher. Both had varying degrees of effectiveness. That is, if we assume that the amount a student reflects on content, both on what one has learned and what one needs to learn, can be estimated based on wiki content and discussion transcripts. MS-CK administered by the teacher, however, was generally more prevalent. For that reason, we have our first indication that the hypothesis for the second research question, that the teacher will be more effective than peers in providing metacognitive scaffolding, will be supported to some extent. I will now turn to the second form of metacognitive knowledge as defined in this paper. That is, general goals knowledge.

Metacognitive scaffolding - general goals knowledge (MS-GGK). The term
"general" is used to distinguish primarily between *content* goals, which are covered under
the section immediately preceding, and all other, more general goals associated with the
activity, such as various non-content rubric criteria (deadlines, how many images are
required, etc…), learning how to collaborate, developing 21st century skills, and so on.
We will begin by looking at peer MS-GGK. In this case, one main theme emerged. That
dealt with students prompting each other to consider the rubric criteria.

Peer MS-GGK. The peer MS-GGK examples which follow are classified as
rubric reflection. Although described here as peer scaffolding, perhaps distributed
scaffolding (teacher and peer) is more appropriate. It was the teacher, after all, who
required students to formatively assess their wikis at the midpoint by considering rubric
criteria. It is unlikely the students would have paid such close attention without this
stipulation. Nevertheless, since it is primarily students that appear in the following
examples, it is classified as peer scaffolding.

Consider first the midpoint dialogue between PC-1 members. It's one we saw
earlier in the complete sequence for Topic 1b (Episode 5). They have just reviewed
Valentina's content about two individuals dating, who then break up. It is meant to be an
analogy for substances not decomposing when they change into a gas. Mariana reacts to
Valentina's comment (on the wiki) that "nothing physically or emotionally changed
about the two people":

Mariana: I would not say that's true.

Luciana: I think she got the creativity. The section b. 4, 5, 9, 13 (Luciana

             must be counting off points from the rubric). She got these 13

points.

Luciana: And I think she, should we give her like.

Mariana: I'm not sure she explained it, like cause, we can understand

because we've taken it somewhat but for someone who hasn't

taken it they wouldn't really understand it.

Luciana: Well, I think she did a good job with her example.

Mariana: Yeah, her example, but this part.

Mariana: Remember, someone who hasn't taken chemistry.

Earlier, this dialogue was described as Mariana demonstrating good intersubjectivity because she had a firm grasp on the goal of the activity. That is, the assignment asked students to explain the misconception in a manner so that even someone who had limited knowledge of chemistry would understand it. Mariana explicitly points this out. This scenario now can be seen in light of the second research question. That is, both Valentina and Mariana can be considered to have provided peer MS-GGK regarding rubric criteria. Valentina did so by virtue of her wiki content, which prompted reflection by Mariana. Mariana did so by nature of her comments, which potentially stimulated reflection by Luciana.

As another example, members of CC-4 discuss how many points should be awarded to each topic during their midpoint discussion. When asked by Camila, "Miss, it's graded out of 8, right?", the teacher corrects her that it is out of 16. Camila then turns to Samuel and ask how many points he feels he should get for his original topic (Topic 1). He replies, "I think….a 12. Put 12". They then move on to Topic 2. Two points of emphasis are necessary here. The first is that the formative assessment score of 12 was

assigned with no discussion whatsoever of the concepts. The second is that there was no contribution from the other two group members, Tomas and Diego. These shortcomings were not uncommon throughout all activities. Therefore, even though the intent of having students review the rubric was to promote deeper reflection on the rubric criteria, fidelity of implementation was generally poor. In the case of CC-4, it clearly represents a missed opportunity. They would have benefitted from discussing the video Samuel had posted, which was quite good, and on topic (see "Dissociation of ions in aqueous solution," 2010) . They also would have benefitted from critiquing his very poor, superficial explanation of the same video:

> This video will explain how aqueous ionic compounds exist as independent ions in a solution in a very crystal clear way. It doesn't matter if you don't have a strong background in chemistry; you will still be able to understand.

This CC-4 example, then, is classified as MS-GGK only because of its *potential* to offer metacognitive scaffolding.

Teacher MS-GGK. Teacher examples of MS-GGK were also primarily dealing with *rubric reflection.* Most of this was done during the introduction day whole group presentation (i.e. before students moved into the computer lab for small group work). The examples which follow are all taken from the PC activity. The teacher's presentation for the CC activity was very similar, however, and the same themes were addressed in both PC and CC (see Appendix's M and N for the PC and CC Teacher "Cheat Sheets"; they describe what Jody intended to cover on the introduction day). In the first excerpt, Jody reminds them of the requirement that each group member needs to make at least one "significant" edit to topics originally assigned to another group member:

> So let's say I did Topic 1 to start with, all of [the other group members] are going to go into Topic 1 and do something that makes a significant change to it. That

could be adding a picture. That could be adding another picture. Or if you like everything that your group member has there… [and you think] I don't want to change this because I think it's done well, what you can do is add a completely new example.

Here, the students were prompted to reflect on exactly what was meant by the rubric criteria which stated "Every group member needs to make at least one ***significant*** contribution to the wiki for **each** topic that was not initially assigned to them" (emphasis in original).

Also during the introduction day, the teacher provides MS-GGK regarding rubric reflection by calling the students attention to the part of the rubric dealing with final expectations for each topic. She emphasizes this to highlight where they need to refer to see what might be missing as the final deadline approaches:

> The other thing on the back is the full rubric for each topic. If you want to make sure your group is getting full points. You can look at Topic 1. Here is what they have to have in the end. Is everything there? If it's not that would be something you could add as a group member? Or if you think something is missing you can post on the discussion board to get one of your group members to change it.

Her final comment about a discussion board posting to "get one of your group members to change it" relates more generally to the second form of teacher MS-GGK. That is, calling students attention to the generalized goal of the activity of *learning to collaborate* in today's world. As we saw earlier, Jody brought this to their attention by mentioning how various companies and government agencies use wikis and that, generally, these types of skills are essential for 21st century workforce preparation. She concluded by noting, "this is like thinking about how to work with other people using technology, collaborating. These are all things frankly you'll have to do in the real world."

So we have seen how this category of metacognitive scaffolding has focused primarily *rubric reflection*, and to a lesser extent, *learning to collaborate*. The instances

of these MS-GGK events were considerably less than the first major category of metacognitive scaffolding, MS-CK, that dealt with content knowledge. One category within the major theme of *recognizing knowledge gaps* remains. That is, *making connections knowledge*. We will now see how it is more like MS-CK than MS-GGK in that occurrences were fairly abundant. Furthermore, it will also be shown to support the hypothesis, not without reservation, that teacher metacognitive scaffolding is more effective than peer.

Metacognitive scaffolding - making connections knowledge (MS-MCK).

Results indicated a fair amount of both peer and teacher occurrences of MS-MCK. The frequency of teacher MS-MCK was greater, however. Often, this additional scaffolding from the teacher took the form of prompting students to reflect on the shortcomings of their creative content. That is not to say that peer scaffolding did not touch on creativity. To the contrary, it often did. However, the teacher's deeper conceptual understanding allowed her to recognize shortcomings that were not nearly as obvious to students. It is worthwhile to remind the reader at this point that creativity is placed in the theme of *making connections knowledge* because, by design, the wiki activities were intended to have students, through their creativity, make connections by drawing on their funds of knowledge. This section will begin with examples of peer MS-MCK. This peer scaffolding will be described under one of two categories which emerged from the coding: *creative connections* and *real-world connections.*

Peer MS-MCK. During focus groups, both PC and CC students described how group members supported one another for making *creative connections*. Such support (that focuses on creativity), for the purposes of this study, is classified as one form of

MS-MCK. Most of the examples which follow we have seen before, in whole or in part, in a different context. For our first examples, we will see that peer MS-MCK *creative connections* often involved sharing ideas on what would make the best images or video. At times this occurred face-to-face and at times by text message, as Sofia and Isabella from CC-2 describe:

EO: OK. Can either of you think about one thing in particular that was especially helpful about what one of your partners did?

Isabella: Well, me and her, like we have our numbers so when she would want help with the wiki we would just text each other and she would just ask me for ideas for creativity like pictures and the web. So we would help each other out.

Sofia echoed Isabella's comments. Isabella later described, and Sofia agreed, how the two-way scaffolding (peer-peer) stimulated deeper thought about finding just the right video to fit the topic:

Isabella: But when we look up videos to try and incorporate each other we really help each other out…I don't know if it was her, but one video we were looking up was, it really didn't have the elements we were looking for. So we would help each other out finding this video…like oh this was better than this one, it fits in more with the topic and all that stuff. So we would help each other out to find creative ways as well.

EO: And when you were considering what you wrote you would work together to sort of refine it to make it better.

Isabella:	Yes.

EO: Is that safe to say?

Sofia: Yes.

EO: Did most of that refinement happen when you were talking face-to-face?

Isabella: Face-to-face as well as texting. We would send pictures to each other. "Oh, maybe you could use this one for this equation".

…..

Sofia: Like the video she kind of helped me look up the video…It took a long time to look for a video and I couldn't really find a video that people come together, so she kind of gave me that idea. The Lion King, how all the animals come.

Here, Sofia is referring to the scene early in the Lion King when all the animals assemble from distant parts of the savannah to honor the newborn lion Simba[20]. The analogy to ions assembling to form a solid lattice structure is not perfect, but it is very creative and useful if you recognize the shortcomings. Based upon the girls' description of their MS-MCK[21], and its concomitant multiple modes of communication, it appears likely that meaningful reflection occurred that connected chemistry concepts to their funds of knowledge (in this case, represented by pop culture) (Gonzalez et al., 1995).

    Other groups expressed similar sentiments about peer scaffolding and creativity.

---

[20] The video was at http://www.youtube.com/watch?v=vX07j9SDFcc. However, as of 7/24/13, the video had been removed from YouTube.

[21] As a reminder to the reader, interactions are classified as metacognitive scaffolding if they are intended to promote reflection, or if the actions are likely to promote reflection, in one of the various categories of metacognitive scaffolding (MS-CK, MS-GGK, MS-MCK, MS-SK). Therefore, regardless of Sofia and Isabella's intent, *their dialogue* is classified as MS-MCK because it was likely to promote reflection on the connections between the video and the chemistry concepts.

Camila from CC-4 recalls how Diego's soccer picture helped her make the creative

connections:

EO: What do you think is the best part about getting help from your fellow

students?

Camila: You get more ideas, like they can have an idea about something that

you didn't have.

EO: Would you say more about how to understand the chemistry or about

how to be creative?

Camila: Both. Like how to understand it and like for a picture you could have.

I remember Diego had a picture of soccer, a soccer field, and he like,

I forget what the topic was but he said the people were the.

EO: Spectator ions?

Camila: Yeah, the spectators. "Oh, yeah. Like the supporters so". (she mimics

what she was thinking at the time)

…

EO: And that helped you out?

Camila: Yeah, after I seen (*sic*) it and I was like, "Oh yeah, that makes

sense".

From her description, it suggests Diego's peer MS-MCK prompted Camila to

reflect in what ways spectator ions were similar to spectators at a soccer game. It is

worth noting, that in spite of her revelation that suggests she came to understand

spectator ions better as a result of Diego's scaffolding, no direct evidence of this exists on

the wiki itself. She never contributed any content to Topic 4 (the topic dealing with

spectator ions).

A second and related form of peer MS-MCK is *real-world connections*. This category differs from *creative connections* in that the former is based on creative analogies that link chemistry concepts with familiar topics (Lion King movie, spectators at a soccer match, etc…). However, in the end, those are still just analogies (i.e. animals coming together to honor Simba isn't *really* an accurate representation of how ions assemble to form a lattice). By contrast, the two examples which follow in *real-world connections* represent a connection the students make to reality, as a result of the peer MS-MCK. For example, consider again briefly the midpoint day discussion of PC-1 regarding the dry ice video:

Daniela:	Now we know what they use in the movies.
Luciana:	What they use in what?
Daniela:	Movies.
Daniela:	Doesn't it look like it?
Luciana:	Yeah.

Here, Daniela and Luciana recognize the familiar fog formed when dry ice is added to water. Daniela can be thought of as scaffolding Luciana, or even Valentina could be thought of as scaffolding both of them, since it was her who originally posted the content that stimulated the reflection and discussion. There is no evidence, however, that this exchange led to reflection. Recall they make no changes whatsoever to the wiki page, in spite of being engaged by the video and supported by teacher scaffolding in the discussion forum.

Another example of peer MS-MCK *real-world connections* occurred for PC-2

members. Mateo, who was absent for the midpoint discussion, had written on Topic 1, "It's like when you boil water it looks like the vapor disappears, but when a flat surface is placed above then you'll see drops of water on the bottom…". As noted earlier, this was an excellent attempt to use not an analogy, but a real world example to help explain the concept that substances don't decompose when they change to a gas. Although potentially useful MS-MCK, it apparently was not effective. Gabriela, who was reading Mateo's content out loud at the midpoint, stated, "It makes no sense (inaudible)". The only edits made to the page after the midpoint discussion were insignificant or incorrect. Therefore, the two examples of peer MS-MCK that deal with *real-world connections* were less than entirely fruitful.

To this point, we have seen examples of peer MS-MCK. Specifically it was brought to bear in the form of *creative connections* and *real-world connections*. At times, the potentially meaningful scaffolding resulted in a less than ideal outcome. We will now turn to teacher MS-MCK where, once again, creativity will be in focus.

Teacher MS-MCK. Creativity also dominated teacher MS-MCK. However, as noted above, the teacher's deeper, more abstracted knowledge of the subject matter allowed her to recognize shortcomings in the students' creativity, and adapt her scaffolding accordingly. Hence, teacher MS-MCK fell into two subcategories: *creative connections* and *creative shortcomings*. One additional, brief category was *activity connections.* This involved connecting different parts of the activity.

Creative connections teacher MS-MCK at times took the form of encouragement to get students started on their creative content. For example, two teacher discussion forum posts for CC-2 (first post for Topic 1; second post for Topic 2) were almost

identical. They struck a positive tone in prompting students to get started. The Topic 2

post we haven't seen before:

> For section "b", like I said previously for another topic, I don't see any content
> here yet so if you are stuck for ideas, discuss it with each other. Don't be afraid to
> be creative! Have some fun with it if you want. And if you use an analogy,
> remember it doesn't have to be perfect. Just make sure to explain the reasons it's a
> good analogy AND the reasons it's not such a good analogy.
> As with the similar Topic 1 post we saw earlier in the complete sequences

(Episode 1, CC-2, Topic 1b) reflection is encouraged, in part, by loosening restrictions.

That is, by emphasizing "it doesn't have to be perfect", the teacher's MS-MCK appears

to open the door for a variety of possibilities, with the caveat that it's important to explain

shortcomings. Both of these groups had better than average outcomes, as we've already

seen. Topic 1 ended up with the Harlem Shake video and Topic 2 the Lion King. More

importantly, students wrote sound explanations to accompany each video. The

explanations tied the video content to the chemistry concepts, providing evidence of

possible effective reflection on the part of the group members.

Those two examples dealt with groups who had yet to add *any* content. Other

instances of teacher MS-MCK that involved *creative connections* dealt with groups that

had yet to add any *creative* content. As one example, we've already alluded to the

instance in which the original content added by CC-4 to Topic 2, was plagiarized. After

the first teacher posting that pointed this out, and a fruitful midpoint discussion, the group

made changes in the right direction (see Figure 21).

The poor grammar and spelling notwithstanding, the new content (green shaded)

that suggests "a specific type of order that repeats itself" and "Precipitate isnint [*sic*] a

molecular type of ions because molecualar [*sic*] type of ions are inpairs [*sic*] and

precipitate isn't [*sic*]" is accurate in terms of illuminating the primary objective of the

Figure 21

CC-4 Group Editing out Plagiarized Content
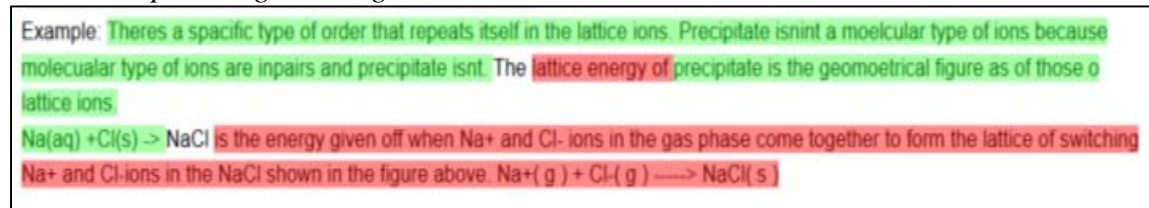
page. That is, that precipitates exist as three-dimensional arrays of ions (lattices) and not

as molecular pairs. That being said, their explanation isn't particular creative, leading to

the teacher's second posting:

> So I would fix up section "b" in two ways. 1) Clean up the grammar and spelling
> a bit, and 2) Add to the creativity a bit. Perhaps you can come up with an
> everyday analogy dealing with lattice structures. Or perhaps adding a video that
> explains what a lattice is in a clear, creative way.

The outcome was less than ideal. Camila, the same CC-4 member who had

contributed text that was copied verbatim, did add a video (see "Lattice Energies -

Chemistry Tutorial," 2011). It was related to lattices, but more specifically on lattice

energies, and basically off-topic. Furthermore, neither Camila nor any other group

member provided an explanation tying in the video with the main concept of overcoming

the misconception that lattices exist as molecular pairs. Therefore, although the teacher

provided MS-MCK to encourage reflection, it appears it was much more effective after

her first posting then the second.

As another instance of teacher MS-MCK *creative connections* in which the group

had existing page content, but lacking creativity, CC-2 received the following second

teacher posting on their discussion board:

> Well, you obviously have more work to do on this one. Although you don't have
> much so far, I do like your first sentence. As you spell out very well, it's very

important to understand that in chemical reactions, atoms are recombined, but the mass (and the overall number of atoms!) doesn't change. But you still need more. Remember to be creative and don't forget to add at least one image, video or link AND explain how it ties in with the main theme.

The comment "you don't have much so far" was not an overstatement. In their attempt to explain the misconception that conservation of matter does not occur in chemical changes, the only student generated content on the page, to that point, was, "The total mass at the beginning doesn't change throughout the chemical equations, they are just being re-combined with out [*sic*] being changed." Although very brief, the statement is accurate and the brevity was not the teacher's main concern. Rather, the students were being scaffolded mainly because it lacked creativity. The intent of the teacher's MS-MCK, in this case, was to get the group to reflect on how they could improve their explanation, not necessarily by expansion, but by connection to more familiar themes. The results were mixed. As I noted earlier, Santiago did in fact post a video that I described earlier as the "perfect complement" to Isabella's text. He then also added a thoughtful explanation. In the end, however, it still wasn't particularly creative.

The final example of *creative connections* deals with the teacher providing an idealized version specific to the primary objective of a particular page. For example, in the PC introduction day whole group presentation, Jody provided the marching band analogy we mentioned earlier. It was her way of offering an example of how students might creatively explain why substances do not decompose when they change from liquid to gas. She said:

> Have you guys ever seen a marching band before? (murmuring can now be heard in the class; one student said "Nope") Anyone not seen a marching band before? So if we have a marching band you'll see them in one formation and then the band, the music changes and they may be spread out and then move around and make a new shape. It's still the same band, same sound, same everything, just in a

different form.

Immediately after those comments, one student called out that the teacher had taken her idea. Although that does highlight a potential pitfall with offering idealized versions (i.e. it may stifle student creativity by steering them *too much* towards the teacher's conception of an idealized version), it also suggests the teacher's presentation amounted to somewhat effective MS-MCK because it had gotten this student to reflect on the connections.

The second creativity oriented teacher MS-MCK category is *creative shortcomings*. That is, unlike *creative connections*, which represented instances in which there was no creative content initially, the following scenarios are ones in which groups had already made an effort and provided evidence of such. The teacher, however, as a result of ongoing assessment, recognized flaws and provided revised support in the form of MS-MCK. One manner in which she did this was proactive. That is, she emphasized to both PC and CC groups during their respective introduction day whole group lessons that shortcomings for an analogy *were* acceptable. The point was reiterated that you don't need to be perfect, but just make sure to explain the shortcomings. Jody said, to the CC groups, "I don't want you to get caught up in how to be creative. Just have fun with this and try to make connections between your life and the chemistry". The same sentiments were expressed on the PC introduction day. As we saw before, after brainstorming with the group about creative ways to explain spectator ions, Jody concluded the discussion by emphasizing that shortcomings were acceptable *if* they are accompanied by an explanation illuminating how they deviate from the concepts being addressed.

Several additional examples of teacher MS-MCK dealing with *creative shortcomings* appeared for both PC and CC activities. Both teacher posts for PC-1, Topic 1, for example, addressed the shortcomings of what was already a very good attempt to explain the misconception that substances don't decompose when a phase change to a gas occurs. Recall, Valentina had posted an image of two friends parting ways. In the first post the teacher promotes reflection on the shortcomings in a general way:

> That image of the two friends going separate ways is also very good and your explanation is just right. I would keep the image and explanation just the way it is. But like most analogies, it seems to me it has at least one flaw. So please also mention in what way this picture is NOT a good analogy for a substance changing into a gas.

Evidence of successful reflection (at least for one group member) was seen in that Valentina updated her explanation by describing that "this analogy might not be the best either because we never know if the people change on the inside at all". Having seen the corrections, the teacher still provides additional MS-MCK because it is not clear Valentina understands the concepts. Jody's revised support in the second post gives more detailed suggestions then the first:

> Consider one of two modifications. First, you could possibly say "imagine" the two people (like Zac and Vanessa; or like the two women) are identical twins. And that each twin represents an *entire* molecule (i.e. each represents a molecule of HCl). This way, when they split apart, one HCl goes one way, the other HCl goes the other way and *everything* is still HCl (not H + Cl). Hence, a physical change!

Jody then proceeds to give a second option, also with considerable details provided. The nature of this feedback might have been too explicit, not encouraging enough reflection. This doesn't seem to have been the case with Valentina, however. As was noted before, she made additional improvements that indicated she had reflected on the latest teacher

comments. In her focus group, Valentina specifically referred to the teacher's creativity-based scaffolding, noting the teacher "did help me a lot".

Returning again to the use of real spectators as an analogy for spectator ions, the first teacher post to CC-4, Topic 4, was geared toward having them refine their existing creative explanation. As with the case immediately above for PC-1, CC-4 had made a decent attempt at creativity, and the teacher's MS-MCK post reflects this:

> For example, you state that the spectators "don't influence the final score, but they do help their team by supporting them and cheering them on". Well, that statement I thought was a bit confusing because wouldn't it be true that if they were a really good crowd, they probably WOULD influence the score a bit because their home team would possible play better. So, I wouldn't get rid of this image and your general explanation. It's pretty good. But discuss it with your group and see if you can come up with a slightly better way to explain it.

Like Valentina in PC-1, the group then makes a respectable attempt at revisions. Their additional text does emphasize the shortcoming that a soccer crowd could help the team win, even though spectator ions don't influence the product in a chemical reaction (see Figure 22).

Figure 22

CC-4 Improvements to Spectator Ions Analogy

An example of where the revisions were not as ideal was found in PC-1 and their jelly bean analogy for Topic 4. After offering similar feedback in the first teacher posting, without any considerable action on the part of the students, the teacher reiterates her concerns about the shortcomings in the second post:

> The main points of my last posting still haven't been addressed so please continue to work on my suggestions. And remember, if you can't find a good image to represent what you feel would be the ideal analogy, then feel free to lose [*sic*; this was meant to be "use"] a less then ideal image, BUT then explain in what ways it's a good analogy and in what ways it is not. For example, I think the black and white jelly bean jar is NOT a good analogy of a compound because the black jelly beans are not "bonded" to the white jelly beans. So either try to find a more suitable item to use for the analogy OR explain what should be different about the image you did find.

Recall the teacher and Luciana had discussed her analogy during the midpoint discussion. That instance of MS-MCK did lead to some reflection because Luciana proposed alternative analogies using flowers, M&M cookies, and macaroni and cheese. The result was a less than ideal outcome, however. As Luciana noted in her focus group, she mistakenly believed the teacher was sending the message she was completely wrong. This final attempt at MS-MCK in the second teacher posting was unsuccessful in that, after the posting, no substantive revisions were made to the page.

As a final example of *creative shortcomings* that led to teacher MS-MCK, consider Topic 2 from PC-1, in which the group is trying to creatively explain the misconception that conservation of matter does not occur in physical changes. As a means of explaining that the change from liquid nitrogen to gaseous nitrogen involves conservation of matter, Daniela wrote, "If someone is blown up then their molecules will be in the air but the number of molecules doesn't change if they are in the body or in the air." This somewhat macabre example actually is a decent attempt at an analogy. It is only valid, however, if the explosion is a physical change (such as what might occur when gas pressure builds up in a closed container), where conservation of molecules does occur, and not a chemical change, where conservation of molecules does not necessarily occur. The teacher posting in response to this time didn't even acknowledge the physical

change option (through my own fault; recall I was the one who first composed the

feedback and I overlooked the physical change possibility at the time):

> Second, your example of someone blowing up doesn't work as well as the water example below it. Because an explosion is a chemical change and the number of molecules at the end does NOT have to be the same as the number of molecules you started with. In other words, in chemical changes, which is not what this topic is about, you do not necessarily have conservation of molecules. But you would still have conservation of atoms! Can you see the distinction, the atoms are all the same, but they can be arranged differently into different molecules. Hence, atoms are conserved but not molecules. Long story short, use a different example. One that is a physical change like the water example.

Perhaps because of this imperfect MS-MCK, students didn't demonstrate evidence of

reflection on connections, and, in the end, no revisions were made to the page.

Having now seen *creative connections* and *creative shortcomings*, the final

category of teacher MS-MCK was classified as *activity connections*. This involved the

teacher prompting the group to reflect and make a connection between different parts of

their activity, such as their creative explanation for part "b" of a page, to their answers

and explanation to part "a". PC-2 received this feedback twice, both times as part of the

second teacher posting. Once was for Topic 1, such as, "you still need to briefly tie in

your explanation from section 'b' with your answer to section 'a'". The other for Topic

4:

> That video is good and has a lot of potential. Now you need to add your own explanation to it to spell out exactly how the video helps to explain the molecular level differences between an element, mixture and compound.

In both cases, no evidence exists that reflection took place. No revisions were made to

either page.

Summary. Metacognitive scaffolding – making connections knowledge (MS-

MCK), taken together with metacognitive scaffolding – content knowledge (MS-CK) and

metacognitve scaffolding – general goals knowledge (MS-GGK), represent the three major categories of metacognitive scaffolding falling under the larger umbrella of *recognizing knowledge gaps*. Although the outcomes from each of these were not always ideal, regardless if the scaffolding came from peer or teacher, the *frequency* of teacher metacognitive scaffolding was greater. This suggests the second hypothesis that teacher metacognitive scaffolding would be more effective is likely to be supported, although perhaps due to relative abundance rather than the relative effectiveness of the metacognitive scaffolding.

Results for all three themes (MS-CK, MS-GGK, MS-MCK) represented instances in which students were prompted to reflect on gaps between their existing and desired cognitions. It is worth reminding the reader that, for the purposes of this study, the desired cognitions were often more evident than existing ones. The outcomes, for example, were generally taken to be a sound understanding of chemistry content knowledge and how that knowledge interacts with general goals, and connectivity to their lives. The current state of the student was often less obvious. For this study, their current knowledge level was assumed to be largely reflected in their updated wiki content. That is, when students write about spectator ions not influencing the product, this is taken to reflect their current understanding. Strategies for getting from where they are to where they need to be (that is, knowing what to do about their knowledge gaps) are the focus of this study's fourth and final theme of metacognitive scaffolding. It is to this that I now turn.

Knowing what to do about it.

Metacognitive scaffolding - strategy knowledge (MS-SK). The preceding

sections on the first major theme of metacognitive scaffolding (as defined in this study),

recognizing knowledge gaps, revealed many examples dealing with *content knowledge*

(MS-CK) and *making connections knowledge* (MS-MCK), and far fewer for *general*

goals knowledge (MS-GGK). The second major theme, *knowing what to do about it*, has

only one category, *metacognitive scaffolding – strategy knowledge* (MS-SK). As we will

now see, in terms of number of occurrences, MS-SK was much closer to MS-GGK then it

was to the abundant MS-CK and MS-MCK. That is, metacognitive scaffolding that

prompted students to reflect on their strategies, and what they might do to improve them,

was infrequent. Furthermore, it is worth recalling at this point that the amount of effort a

student puts into the task is considered a strategy for the purposes of this study. Not only

was MS-SK infrequent, it was also not varied, almost always dealing with prompting

students to reflect on their amount of effort.

> *Peer MS-SK.* Instances of peer MS-SK from PC and CC were almost non-

existent. The only discernible instances of one group member overtly making an attempt

to motivate others involved PC-2. In this case, Gabriela took the initiative the day before

the midpoint to send her fellow group members an email trying to motivate them. Hence

the one and only category of peer MS-SK is referred to as *increase effort*. Realizing each

member's first draft was due the next day, and that there was currently limited content on

the wiki, the email urged them to get going. The three of the group members who

participated in the focus group explain:

> EO: Why did you send them the email? Were you trying to motivate
>
>   them?

> Gabriela: Yes, I was. And to remember the due date.

EO: Was that helpful? (asking Victoria and Lucas)

Victoria: Well, I didn't read my email.

EO: You didn't check the email.

Lucas: I checked it.

EO: Did it help remind you that we need to have this done by

             tomorrow?

Lucas: (nods yes)

As we saw earlier, the wiki history supports Lucas' answer. Most of this pre-midpoint content was added at 9:43 PM the day before the midpoint, presumably after Gabriela's email. Although Victoria does not appear to have read the email, Gabriela's additional urging during the midpoint discussion appears to have motivated her. After Gabriela jokingly gave her a hard time about having not started yet, Victoria promised to get started that evening. She, in fact, did add a modest amount of content during the midpoint and again later that night.

Teacher MS-SK. Teacher initiated MS-SK was more frequent then peer, but not by much. It did, however, have an additional component in addition to *increase effort*. During the introduction day for both PC and CC, the teacher began the whole group presentation by having the class reflect on their wiki trial run performance. Thus, I refer to it as *trial run reflection*. As they always do, students had a "catalyst" question waiting for them as they entered the room. The questions were 1) what went well [with the trial run], and 2) what does your group need to do better to improve this time?

Student answers to these questions were honest evaluations of their performance. As conveyed by the teacher (who went around the room reading what student's had

written on their "catalyst" sheet), students in the PC class commented "we need to actually do the project", "we need to actually complete what we way we are going to do", and "if we assign each other the work we need to make sure the other people in the group do their work". Similar sentiments were expressed in the CC class, including noting it was challenging "making sure people were doing their work". It is not known the extent to which this activity encouraged students to reflect on *future* strategies, such as what they might do on the current wiki activity.

Like *peer MS-SK*, teacher MS-SK also entailed scaffolding intended to get students to *increase effort*. This usually came in the form of a discussion forum posting. Both PC and CC groups received one or more postings such as "We NEED to get this going! Let me know how I can help!" or "Hello group! We obviously need a lot more here. Discuss it with each other if you are stuck for ideas. Don't be afraid to be creative". Such curt comments were generally offered when the students had put little or no content on a particular page. As with the catalyst activity just described, it is not known just how much this spurred students to reflect on their amount of effort.

Summary (Research Question 2). Nothing from this brief, final section on the different themes of metacognitive scaffolding suggest the hypothesis for the second research question was not supported. That is, that teacher metacognitive scaffolding is more effective than peer. Two of the other categories of metacognitive scaffolding, MS-CK and MS-MCK had a much higher frequency of teacher MS than peer. The remaining category, MS-GGK, had roughly the same about of MS for teacher and peer.

The fact this last section on MS-SK was so brief might be the most telling point. That is, if metacognition involves recognizing knowledge gaps and knowing what to do

about those gaps, then it is possible students need considerably more scaffolding on strategies to use once they identify gaps. It follows they might also need additional metacognitive scaffolding to promote reflection on those strategies. We will now turn to the Discussion chapter where we will take a closer look at interpreting this issue as well as the data more generally for both distributed metacognitive scaffolding (second research question) as well as level of cognitive conflict (first research question).

Chapter 5: Discussion

Research Question 1

Research Question 1: Is there a difference in academic achievement between a treatment

and control group on selected concepts from the topics of bonding,

physical changes, and chemical changes, when Latino high school

chemistry students collaborate on a quasi-natural wiki project?

Hypothesis 1: As measured by posttest scores, the academic achievement of the

treatment group will be greater than that of the control group.

Overall results indicated no significant difference between the wiki and normal

instruction groups. Therefore, hypothesis 1 is not supported. However, students in the

chemical changes wiki group ($n = 14$, $M = 4.25$, $SD = 1.35$) outperformed their normal

instruction (NI) counterparts ($n = 31$, $M = 2.88$, $SD = 2.03$) in a manner that was

statistically significant ($t = 2.88$, $p = .027$, $df = 43$). Most of this advantage of the wiki

group can be attributed to questions five and six on the chemical changes posttest. Both

of these dealt with common misconceptions of submicroscopic representations of

precipitation reactions. On these questions the wiki group ($n = 14$, $M = 1.50$, $SD = .20$)

did significantly better than the normal instruction group ($n = 31$, $M = .55$, $SD = .85$) and

the effect size was very large (Cohen's $d = 1.33$). Furthermore, this study demonstrated

that wiki students were significantly better at overcoming the misconception that aqueous

ionic reactants exist as molecular pairs (χ^2 (1, $n = 45$) = 11.85, $p = .001$). The effect size

phi = .561 was large.

A large part of the analysis which follows, then, will focus on differences in

distributed scaffolding between the highest performing group (CC) and the lowest

performing group (PC). In doing so, I will unpack how differences in intersubjectivity

and calibrated assistance may have been responsible for group differences. An

underlying presumption of this analysis will be that the advantages experienced by the

CC group fostered, to a greater extent than the PC group, medium levels of cognitive

conflict. Furthermore, I will demonstrate how presenting the same underlying concept in

different contexts contributed to the disparate results between PC and CC groups.

Additionally, I will analyze how Vygotsky's formulation of signs and tools can inform

our understanding of the wiki group's ability to overcome misconceptions dealing with

submicroscopic representations. Finally, this Discussion section on the first research

question will address the overall result of non-significant difference between groups. In

particular, I will examine how the aversion to peer editing hampered the active social

negotiation required to stimulate cognitive conflict.

Comparison of Physical Changes and Chemical Changes activities. The

central, binding assertion of this study was that distributed scaffolding is better able to

promote medium cognitive conflict than teacher-student, peer-student, or computer-

student scenarios can do independently. Given the results, this section will recast that

statement slightly. That is, I will make a case that the way in which distributed

scaffolding promotes medium cognitive conflict is by either (1) avoiding high cognitive

conflict, or (2) avoiding *perceived* low cognitive conflict, with the former being the more

likely scenario. That argument will then be followed by examples and analysis of

differences in intersubjectivity and calibrated support between PC and CC activities. An

assumption will be that these differences favor the CC group in avoiding both high

cognitive conflict and perceived low cognitive conflict.

    Default levels of cognitive conflict. In the Moskaliuk, et al. (2009) wiki study, the low incongruence (i.e. low cognitive conflict) condition was one in which the wiki was prepopulated with familiar content. That wiki had information from all the schizophrenia pamphlets, which the students had recently read. Researchers presumed the subjects understood what they had read in the pamphlets and thereby had strong wiki content familiarity. This promoted low cognitive conflict. I believe it is unlikely the students in the current study, generally, ever experienced this similar level of low cognitive conflict. The most explicit evidence of this is their very poor pretest scores. This suggested they were not *at all* familiar with the prepopulated content when the activity began. Therefore, their degree of cognitive conflict at the outset was much closer to the high incongruence scenario[22] in Moskaliuk et al. (2009). We have seen that instruction in Vygotsky's ZPD involves student "participation *slightly* beyond their competence" (Rogoff, 1990, p. 14; italics added). If slightly beyond their competence is akin to medium cognitive conflict, then most students began this study *well beyond* their competence. One means of effective distributed scaffolding for these chemistry students, then, would involve *reduction* in the level of cognitive conflict, from high to medium.

    A second, less prevalent level of conflict is also likely. Instead of recognizing

---

[22] Recall, in that case, the high incongruence condition was one in which there was *no* content on the existing wiki pages. According to the authors, this created a considerable mismatch with the student's existing cognitions because the students had considerable knowledge of schizophrenia (presumably). As a point of clarity for the reader, this mismatch, which leads to high cognitive conflict, arose in a different manner than the current study. For the Latino high school chemistry students, there was considerable content on the pages to begin with, of which students were expected to add to. This template content, dealing with abstract chemistry concepts, was not *at all* familiar to the students (as evidenced by poor pretest scores). Thus, high cognitive conflict was very likely because, in this case, it was the *students' knowledge* that was limited to begin with. This contrasts the Moskaliuk et al. study (2009), in which the knowledge on the *wiki itself*, to begin with, was limited. The main point is, in either case, high cognitive conflict resulted.

shortcomings in their understandings of content, students may at times have had "overly personal and individualistic interpretations" (De Lisi, 2002, p. 7). That is, they thought they understood it when, in fact, they didn't. This represents *perceived* low cognitive conflict. The extent that this occurred is probably minimal. Evidence of such "overly personal" interpretations might be a student who expressed unwarranted confidence in their conceptual understanding. Such displays were not found. Nevertheless, perceived low cognitive conflict cannot be discounted entirely. Perhaps an example is seen when PC-1 members Luciana and Mariana are reviewing the Topic 1 content contributed by Valentina. Luciana seems impressed with surface features of the explanation, rather than the underlying concepts, and states "Well, I think she did a good job with her example". Mariana, however, recognizing some flaws in Valentina's content, asserts that she isn't so sure. It seems here that some critical aspects of the problem have been overlooked by Luciana, suggesting perceived low cognitive conflict might be occurring. Therefore, a second means of effective distributed scaffolding would be *raising* the level of conflict, from perceived low to medium.

We will now take a closer look at first, avoiding high cognitive conflict, and second, avoiding perceived low cognitive conflict. In doing so, the objective will not yet be to discuss the disparate PC and CC results, but rather to provide a foundation for that analysis which comes later.

Avoiding high cognitive conflict. This study was not designed to unequivocally recognize discrete levels of cognitive conflict. Nevertheless, some scenarios, such as the one just discussed with Luciana and Mariana, *appear* to apply to a particular level. In that case, Luciana was perhaps experiencing perceived low levels of cognitive conflict.

A level of high cognitive conflict, on the other hand, might have been reflected when PC-2 member Gabriela was trying to come to terms with the teacher's discussion forum feedback. As she read the posting, she interjected comments such as "I need a break", "Oh my Jesus!", and "This is giving me a headache". She confirmed in her focus group that she was feeling overwhelmed and should have taken it "one step at a time". Cognitive conflict results when individuals recognize a gap between their existing schema and new information (Niaz, 1995). Here, Gabriela certainly seems to have recognized a gap. With comments like "Oh my Jesus!", if there were examples of high cognitive conflict that revealed themselves plainly in this study, this is certainly one of the them.

Considering the abstract, conceptually difficult nature of chemistry, Gabriela's reaction is not surprising. I suggest the only reason more students didn't express such dramatic sentiments is due to them either not making their thinking visible, or not giving enough effort. Effective distributed scaffolding then, for a high school chemistry course, generally needs to reduce the level of conflict from high to medium. In some respects, mathematics is conceptually difficult like chemistry is, and Vygotsky noted, "if I do not know higher mathematics, demonstration of the resolution of a differential equation" would do him no good (L. S. Vygotsky et al., 1987, p. 209). His point was he can't move from point "a" to point "b" unless point "b" is within striking distance.

Therefore, in order to reduce the level of cognitive conflict to the medium level, in order to put students within striking distance, distributed scaffolding must feature mechanisms which facilitate students like Gabriela in taking it "one step at a time". Whatever their existing cognitions, the scaffolding should reduce the conflict so as to

take them to the next *accessible* point. That next point is not necessarily their final destination. That might have to wait. Often the teacher is needed, as the content expert, to enable this mechanism. At other times, however, reduction in level of conflict might be best achieved through peer intervention. The type of peer scaffolding, for example, that suggests using Harlem Shake or Lion King videos as accessible analogies.

Another possible example of high cognitive conflict might have been revealed in the form of plagiarized content. For some assignments, students might have little comprehension of what they've read and resort to copying a text verbatim (De Lisi, 2002). Examples of this occurred more than once in the study. As one example, CC-4 member Camila's early contribution to Topic 2 included cutting and pasting a definition of lattice energy. That it represented high cognitive conflict was almost certain as the definition was far more technical than the activity requirements called for (and, for that matter, more technical than is typical for any high school chemistry class below the advanced placement or accelerated levels). The primary topic dealt with understanding that precipitates exist as lattices. To introduce lattice *energies* took it well beyond the intent of understanding relatively simply geometric configurations.

Camila later compounded her error by linking to a video on lattice energies. The educational value in this case was again no greater than plagiarized text. Camila failed to provide an accompanying explanation for the video. Recall that web searches are classified as computer scaffolding for the purposes of this study. Thus, this represents where distributed scaffolding was needed, in the form of teacher or peer intervention, to help Camila understand these text and video contributions were inappropriate. Stated another way, teacher or peer scaffolding was needed to help her select alternative text and

video, both of which had some elements she could relate to and thus reduce the level of cognitive conflict. This is in fact what happened as a result of both teacher and peer scaffolding, at least for the text. The teacher prompted her to look up the definition of "lattice" (not "lattice energy"), and her group member Samuel helped her compose an updated definition, in their own words. The shortcomings of the linked video, however, were not redressed. The primary point is that, once again, in a high school chemistry wiki activity, effective scaffolding often corresponds to a reduction in conflict and thus helping students avoid ongoing levels of high cognitive conflict.

Avoiding perceived low cognitive conflict. Moving students to a medium level of cognitive conflict might also involve helping them raise perceived low levels of conflict. Piaget believed that peers were best suited to do this. They could recognize "overly personal and individualistic" interpretations (De Lisi, 2002, p. 7).   Mariana exemplified this when she corrected Luciana on PC Topic 4a, #6 and #7. Recall Luciana first stated, "Yeah, but I guessed they're a compound because it's two different ones". Mariana then tried to steer her group member to the correct understanding that the diagrams represented elements, and not compounds. In effect, her efforts amounted to an attempt at raising Luciana's conflict level.

In the current study, however, instances such as that one were uncommon. Generally, the teacher was better at identifying perceived low cognitive conflict. Consider the numerous times the teacher discussion posts pointed out creativity shortcomings, for example. The students who posted the creative content presumably felt they had made a reasonable analogy connecting the "real-world" with the chemistry concepts. By contrast, the only explicit example of peers pointing out a creative

shortcoming was when Mariana from PC-1 expressed disagreement with Valentina's assertion that nothing physically or emotionally changed about partners who end up going their separate ways.

When students receive scaffolding from an adult they too may be unable to avoid perceived low cognitive conflict, but for a different reason. Piaget believed a child is less likely to critically evaluate teacher scaffolding (Rogoff, 1990). Perhaps this is explained by the deference afforded the teacher. Students from both PC and CC groups indicated they gave their Chemistry teacher the final word when it comes to content. Luciana's comments suggested a preexisting level of skepticism for peer feedback. She says of her peers trying to help, "they would try but I wouldn't get it. I think it would just be better to ask the teacher". Her opinion seems to be that the teacher is far more likely to explain it in a way she would understand. CC-2 members Sofia and Isabella felt similarly. Isabella elaborated that the best way to learn chemistry was to use the "real definitions and real examples" provided by the teacher and not to have to deal with creative examples like "soccer fields or the Harlem Shake".

From a Piagetian perspective, however, this teacher scaffolding could end up being "too coercive", steering the child to the "teacher's conception instead of allowing them to construct their own" (Driscoll, 2005, p. 214). In other words, perceived low cognitive conflict could remain because the student never really made sense of the content for themselves, although they convinced themselves they had. In any event, the primary point is that from time to time distributed scaffolding in a high school chemistry class will likely need to address raising student levels of cognitive conflict. That is, from perceived low levels to medium levels. Both teacher and peers might have trouble

faithfully executing this, given some of the obstacles discussed here.

Summary. The objective of the preceding sections of avoiding high cognitive conflict and avoiding perceived low cognitive conflict were meant to lay the foundation for what follows. That is, I will now turn to an analysis of scaffolding characteristics that will help us understand the different outcomes for the PC and CC activities. It was not possible to indisputably know the level of cognitive conflict a particular student was experiencing, given the experimental constraints. However, in the analysis of intersubjectivity, calibrated support, and fading that we now turn to, it will be presumed that instances which reflect more effective scaffolding for CC groups, relative to PC, also reflect more effective means of avoiding high cognitive conflict or perceived low cognitive conflict.

Analysis of intersubjectivity. In this study, two ways in which intersubjectivity was fostered was by establishing *combined task ownership* (Puntambekar & Hübscher, 2005) and helping learners build *knowledge bridges* (Wu, 2010) between current and prospective knowledge levels (the third means, having the learner *understand the goal*, is not featured here due to no discernible differences between PC and CC activities). Both of these were operationalized by encouraging student creativity. I suggest that by being creative, and drawing upon their "funds of knowledge" (Gonzalez et al., 1995), it helps defend against high levels of cognitive conflict. By design, students are compelled to find their own point of reference to build off of. To put it in Vygotskian terms, it guards against instruction that is far beyond the learner's ZPD. It encourages students to relate the new chemistry content to their preexisting cognitions.

Results suggest the teacher was very supportive of both PC and CC groups.

However, her fostering of creativity was, in subtle ways, more without reservation for CC students. For example, the teacher supported CC-2 member Santiago's idea to incorporate the Harlem Shake by first asking, in an unmistakable nonjudgmental tone, "How does that help?". She reinforces this by stating, "It's your analogy, you can do what you want". In another instance, during the CC whole group brainstorming activity, one student suggested the announcers in the game would make a good analogy for spectator ions. This is contrary to the norm of using the actual spectators as a reference point, and Jody was certainly well aware of this. Note her initial reaction, however. "Why does that analogy work?" was delivered without skepticism. She does eventually emphasize, as she should, that these analogies have their shortcomings. The key is, when encouraging task ownership and knowledge bridges, in the form of creativity, the teacher's emphasis on shortcomings doesn't come until *after* the unqualified support.

Compare this to two PC incidents in which the skepticism demonstrated by the teacher was foregrounded. PC-1 member Luciana was struggling to revise her jelly bean analogy, the image that represented compounds in particular. To her credit, on the spot during the midpoint discussion she was able to suggest M&M cookies, macaroni and cheese, and flowers as alternative examples. When Luciana suggested flowers, the teacher's initial response included "But like you don't really ever find stems and flowers separately from each other". In other words, unlike the CC examples, here Jody emphasized the shortcomings from the outset, rather than first sugar coating it with "Why does that analogy work?" and "How does that help?", delivered in a positive tone. Luciana confirmed in her focus group that what she took from that exchange was that she must be wrong.

In another example, after Mateo got up the nerve to speak up during the PC whole group brainstorming activity, he suggested the misconception that substances don't decompose when changing state to a gas could be compared to a unique friendship scenario. Specifically he said, "Like you and your friends, like if you guys were enemies and now your friends, you're still the same person, just now friends". Jody's first response was, "Maybe, kind of, but". Although her tone was gentle, Mateo's reaction suggests that to him it was perceived as a rebuke. For the remainder of the session, in spite of excellent alternative analogies offered by the teacher, including some of which built off Mateo's friends example, Mateo appears to feign interest with curt replies such as "mmmm" and "OK". As noted earlier, Mateo did not attend his focus group and was not available to confirm this interpretation. The primary point here is that in the CC activity as a whole, combined task ownership and knowledge bridges, in the form of creativity, was fostered in a more absolute manner. As conceptualized in this study, CC students thus experienced greater intersubjectivity.

Mortimer and Wertsch (2003) suggest that in science classrooms, the teacher is perceived by students as having "clear, undisputed understanding of speech genres and the meanings of terms he or she uses" (p. 235). Perhaps this is how PC students Luciana and Mateo regard their teacher. That is not to say the classroom environment was not welcoming and the teacher-student relationship poor. To the contrary, the classroom walls were adorned with student work samples, many with comments of enthusiastic teacher approval. The students generally responded well to the teacher's warm, yet businesslike approach. The point is when it comes to disciplinary language and understandings, in particular for science, the teacher is considered to have unrivaled

status. Several students affirmed this, in both PC and CC groups, as we saw a short while

ago in the examples of deference. What all this means for establishing intersubjectivity is

that it might be critical for a science teacher, when encouraging creativity, to carefully

consider the timing of their feedback. That is, statements which address shortcomings

and that might sound critical, which are certainly necessary, perhaps should always come

after more supportive, reassuring statements.

Such an approach might prove especially fruitful when the teacher and student are

from different cultural backgrounds, as was the case in this study. Wu (2010) noted how

the establishment of intersubjectivity is mediated by an individual's background and

culture. This phenomenon is perhaps especially applicable in urban science classrooms.

The nature of the discipline itself is characterized by "the rigid ways that scientific

concepts and principles are presented" (Emdin, 2009, p. 240). These same concepts are

"generated by individuals that the students will never have access to or who they feel

they cannot identify with" (2009, p. 240). What all this amounts to, if criticism is offered

too soon, is potentially exacerbating the distance students perceive to exist between

themselves and the "expert" teacher, especially when the science teacher is of a different

cultural background.

Elmesky and Seiler (2007) suggest the greater this perceived distance the more

negative feelings that are generated toward the discipline as a whole. To the degree that

this is the case, this suggests a science teacher walks a fine line. Consider the case here

in which the emphasis on creativity diverted from the "rigid ways" in which science is

often presented. It amounted to shifting the balance of task ownership in the direction of

the student. Therefore, since these instances are uncommon in the "rigid" science

classroom, and science students are thus unfamiliar with them, it might be important to always begin feedback of student creativity with encouragement, postponing more critical comments. This approach is consistent with sending the message that the learner was an equal rather than a subordinate, something Piaget suggested was necessary if an adult is to facilitate intersubjectivity (DeVries, 2000).

A presumption here has been that establishing intersubjectivity contributes to reducing high levels of cognitive conflict. Students are then better able to aid the teacher in finding starting points that will get them where they need to go. Alternatively, it is possible the issues mentioned here involving creativity might help a student avoid perceived low cognitive conflict. For example, we've seen several times that CC students Sofia and Isabella preferred the teacher directed lesson over the more open-ended wiki approach. They preferred not having to use the "soccer fields or Harlem Shake" to make their points. They seem to suggest "What's the point of that?" and it's much more efficient to just have the teacher tell you what you need to know. Perhaps this is an example of students who benefitted considerably from the wiki activity, without realizing it. That is, although they prefer the teacher directed lesson, that doesn't mean it's in their best interest. They may have a comfort level with hearing it from the "expert" teacher and may perceive low levels of cognitive conflict as a result. It troubles them to be pushed to be creative and find connections to their "funds of knowledge". However, the very nature of doing so, including sending text messages back and forth to find just the right video, was more of medium conflict type of activity.

Summary. Intersubjectivity was promoted through combined task ownership and knowledge bridges, both of which were manifested by encouraging student creativity.

Results suggested a higher degree of intersubjectivity existed in the CC activity because of the subtle, yet discernible differences in the manner in which the teacher scaffolded student creativity. In the next section on calibrated assistance, we will again discuss results which suggest more effective scaffolding of the CC groups.

> ***Analysis of calibrated assistance.*** This section will analyze calibrated assistance, the second major characteristic of scaffolding. It will be divided into two subsections, both of which were emergent categories that offer possible explanations for the differing results of the PC and CC groups. The first deals with the level of participation within groups. As a point of reference, the highest levels of participation for a group will be taken to mean that *all* members were actively engaged on *all* topics. The second subsection addresses the extent to which group members focused on the *primary* objective of a particular topic.

> *Participation levels.* For a conceptually difficult subject, calibrated assistance that often focuses on content is, of course, critical. However, evidence from this study suggests it is equally important for distributed scaffolding to address participation levels. Both PC and CC groups demonstrated uneven participation. Face-to-face discussions rarely involved all members of the group collaborating simultaneously. Instances of students working independently, or working with just one other group member, were not uncommon. In addition to these face-to-face interactions, we've seen that online peer editing was minimal. In the PC-1 complete sequences, for example, we saw that Mariana was the only one to edit the content Valentina originally posted, and that amounted to only one edit. The remaining group members Daniella and Luciana not only made no edits to Topic1, they showed no evidence whatsoever of considering the relevant

misconception. CC participation was also generally poor. Recall from the CC-2

complete sequences, Santiago added considerable original content, Sofia made one edit,

and Isabella none. In spite of this lack of peer editing, however, other evidence from

focus groups and face-to-face dialogues suggested the Sofia and Isabella had greater

engagement then did Daniela and Luciana from PC-1. Therefore, more frequent

calibrated assistance aimed at participation levels, especially for PC groups, would have

been beneficial.

This additional or modified calibrated assistance might need to originate from the

teacher.   As described in the literature review, adults have been shown to "elicit greater

participation then child partners" (Driscoll, 2005, p. 258, citing Radziszewska and

Rogoff). For example, only as a result of the "teacher's persistence" did Year 11

Australian chemistry students remain focused on their objective of considering a

construction metaphor when learning stoichiometry (Thomas & McRobbie, 2001, p.

254). We have seen how Piaget emphasized the importance of diagnosis because it is

critical to establish where a child is at before designing instruction. I suggest then the

teacher needs to play a leading role in extending this assessment to include student

participation levels. Then, in addition to revised support that addressed content, it would

also focus on ensuring all students were engaged on all topics.

Two points of emphases are necessary here. First, it is recommended that

teachers take advantage of wiki monitoring features. This includes being able to monitor

student contributions any time by logging in and checking the wiki history. It is also

possible to receive email notifications whenever these edits occur. The second point is

that even when they have limited time, they can quickly scan the wiki history and

estimate the quantity of content contributed by a particular student. This cursory review can be worthwhile. Moskaliuk et al.(2009) found a significant correlation between assimilative knowledge building (content added that does not restructure existing content) and student acquisition of factual knowledge. Furthermore, there was also a correlation between accommodative knowledge building (restructuring the wiki content) and conceptual knowledge acquisition (Moskaliuk et al., 2009). This suggests that a quick scan might provide useful data. It might be enough to detect a very limited contributor, or someone who has not restructured any existing content. The teacher could then contact the student and provide generalized feedback before the student fell too far behind.

This is not to say that participation levels were not addressed at all for both PC and CC groups. Recall the peer scaffolding that Gabriela provided her teammates by emailing them the night before an important deadline. Her intent was to motivate them since their participation to that point had been limited. Both the wiki history, and fellow PC-2 member Lucas, confirmed the email was an effective motivator. Furthermore, on more than one occasion, teacher calibrated assistance intended to raise participation levels included discussion board comments such as "Hey team! We need to get going on this! Let me know if you need my help!". The degree to which these comments are successful might depend on whether or not they are not directed toward one particular individual. It was noted earlier that computer scaffolds are sometimes ineffective because scaffolding theoretically needs to be tailored for each learner. Pre-programmed prompts might offer support that actually hinders a student's progress because they were not ready for a particular comment. It is hard to imagine that "Hey team! We need to get

going on this!" would negatively impact anyone. Perhaps, however, to be effective and positively impact the group, the scaffolding needs to be specific and targeted to individuals.

Additional or modified calibrated assistance, then, that addresses participation levels might have proven beneficial. Although both groups demonstrated limited participation in one form or another, it was a characteristic more closely aligned with PC groups. The degree to which groups focused on the primary topic also favored CC groups, and it is to this that I now turn.

Topic focus. The previous section began by conceding that calibrated assistance which focused on content is critical. This section explores that assertion in greater detail. Cognitive conflict can be generated in various ways, including a surprise result that runs counter to one's expectations (Niaz, 1995). This was never more evident than when PC-1 members Mariana, Daniella, and Luciana watched the dry ice video. They expressed their surprise and delight with comments like "That's cool" when reacting to the various demonstrations. What we haven't seen yet is their even greater surprise at the end of the video. When the pressure buildup shot the rubber stopper off the bottle, and up to the ceiling, one member of the trio commented, "Is it that strong? Oh my God!".

As with Gabriela's reaction of "Oh my Jesus!", this was one of the rare instances when evidence of cognitive conflict was so overt. Unfortunately, however, the students never directed their attention to the misconception intended to be addressed. The buildup of carbon dioxide gas (in the stoppered bottle), that led to the rubber stopper being shot like a rocket, provided an excellent catalyst to initiate a discussion about whether or not substances decompose when they change state to a gas. This discussion never transpired.

This section then will analyze calibrated assistance focused on content, in particular focused on the primary content. It will reveal another difference between PC and CC groups. To a greater degree than CC groups, PC groups needed additional calibrated assistance that would have redirected their attention to the primary objective.

As those students reacted to the dry ice video, scaffolding was needed that moved them beyond the "wow" or "that's cool" factor. This is not to discredit the positive impact of the dry ice video. It clearly engaged the students and produced the most demonstrative reactions throughout all three wiki activities. What was missing, however, were strategically placed questions that would redirect the students so they focus on the relevant misconception. The questions might start with "Why do you think the rubber stopper shot up and hit the ceiling?". Assuming students would identify the gas pressure buildup as the cause, the next question might be, "How is that gas different from the solid carbon dioxide (dry ice) that remained in the bottle?". The specific questions, of course, would be calibrated to address the specific needs of the group. The point is, at the moment one of them exclaimed "Oh my God!", it represented a perfect opportunity to shift the conflict generating question from "Is it that strong?" to one dealing with the primary objective.

Who would be best suited to redirect the group with the right questions? It was evident none of the three members present were prepared to do so. The absent member, Valentina, might have been had she been there. She was not only a strong performer on the activity overall, but it was she who had posted the video in the first place. Perhaps she might have stimulated a topic-focused discussion. Piaget would support this as preferable to adult interaction, which he believed might lead to "mindless conformity"

(DeVries, 2000, p. 203). In theory, this seems plausible. In practice, I believe less so, at least for a high school chemistry class. It has been demonstrated that peers have difficulty generating questions that promote metacognition among their fellow students (Choi et al., 2005). Considering the chemistry teacher has had years of learning science in general, and chemistry in particular, it seems more likely they are better suited to redirect the students to the topic. Even for them it is a challenge, to be sure. The teacher needs to guard against a questioning scheme that generates too high a level of cognitive conflict (i.e. essentially talking "over the heads" of the students). Nevertheless, the advanced content and pedagogical content knowledge of the instructor suggests teacher calibrated assistance, again, needs to lead the way.

Another difference between PC and CC scaffolding was that the face-to-face teacher calibrated assistance for CC groups was more content focused to begin with. This wasn't by design, of course. Generally, the interactions between student and teacher were dictated by circumstance. Jody, for example, assisted more than one PC group with locating the discussion board teacher feedback. She did so because students were unsure how to find it. Such procedural scaffolding also took place for the CC activity. However, content focused scaffolding was still more prevalent, such as the following exchange between Jody and CC-2 member Isabella:

Teacher: The amount of mass you have in the beginning should be the same as what?

Isabella: As the result at the end.

Teacher: As the result at the end, because what did you do with those atoms?

Isabella:	Aren't you just combining them but the total mass number just gets moved (note: She said "combining" not "recombining"; but the teacher in next line says "recombining)
Teacher:	Yep, you're just recombining them so your mass is also there; it's just maybe organized in a different way.

The point isn't that none of this content focused scaffolding occurred in the PC activity. Rather the point is that, more than once, opportunities to redirect PC students to the primary objective were missed. Such missed opportunities were less prevalent in the CC activity.

Summary. Like the subtle, yet discernible favorable scaffolding the CC groups received regarding intersubjectivity, the same can be said for calibrated assistance. In the latter case, the PC groups at times were in need of additional or modified participation level and topic focus scaffolding. It is not that CC groups couldn't have used more of this; it's just that in their case the omission had less impact. From here, I will now briefly discuss fading, the third and final major characteristics of scaffolding.

Analysis of fading. A key aspect of fading is the gradual withdrawal of support. Transfer of responsibility from the teacher to the learner is passed along in a non-abrupt manner (F. Wang & Hannafin, 2008). If for no other reason, this gradual tapering might be what students need to boost their confidence (Wu, 2010). Perhaps this confidence building goes hand in hand with receiving support at least long enough to become comfortable with the expectations and technical features of an unfamiliar activity. CC-2 member Santiago noted that the activity was fun "once you get used to it". During the PC teacher interview, Jody echoed these same sentiments, stating this is the type of

activity "that keeps getting better with more use". Whatever the primary benefit of fading, confidence building or otherwise, it has been described as the "defining characteristic of scaffolding that distinguishes it from other forms of support" (Wu, 2010, p. 26). If this is the case, this alone might explain the overall non-significant result between the wiki and normal instruction group. Neither the PC nor CC groups received non-abrupt, gradual withdrawal of support.   Perhaps one reason that explains the superior performance of the CC group is that fading, in their case, was simply less necessary.

Of the three primary characteristics of scaffolding described in this paper (intersubjectivity, calibrated support, and fading), perhaps fading more than any other can benefit from *distributed* scaffolding. Teaching 15 or more teenagers a conceptually difficult topic like chemistry is challenging, and to expect the teacher alone to provide gradual removal of support, based on the individual needs of each student, is unrealistic. Two recommendations will be offered to at least move closer to a more faithful implementation of the scaffolding model. That is, one in which fading plays a more prominent role. First, as suggested several pages back, not only do wikis provide a platform for making students thinking visible, they also allow convenient access so teachers can "peek in" to "see" this thinking. At any time, from any location with internet access, a teacher can monitor progress. As a result of this ongoing assessment, revised support can be offered in the discussion forums, and the support can be calibrated for each learner. To be perfectly clear, this would take considerable time and energy for a teacher. This was especially true in the case of Jody, who in addition to being a second-year teacher, was also taking two graduate courses per semester in the evenings. The

recommendation then, to be realistic, applies to the best case scenario for teacher availability.

A second recommendation follows from the first. The teacher can take note of who the top performer is in a particular group when performing ongoing assessment (i.e. when "peeking in" to the wiki pages). If the teacher then does not have time to also compose revised support, calibrated for each member of the group, one quick email or face-to-face communication to only the top performer can be executed. It would encourage *them* to scaffold their fellow group members. We have already seen several times that some students prefer feedback from the teacher. Other students, however, felt differently. PC-2 member Victoria noted, "I think I learn better in groups, like from somebody else other than the teacher". The main point is that no students were completely averse to peer assistance and if the amount of peer scaffolding is to increase it might take the teacher to promote it. Having said that, the teacher would still need to have realistic expectations; it is questionable whether even top performers would be able to offer the nuanced support associated with fading, considering it is adults who often have "greater sensitivity and demonstration skills" (Rogoff, 1990, p. 165). Nevertheless, additional interactions between peers, however imperfect, might at least simulate one or two of the weaker group members to later visit the teacher and seek her support directly.

Summary. Fading is the third and final characteristic of scaffolding, as conceived in this paper. The differences between PC and CC groups seen for intersubjectivity and calibrated assistance were not observed for fading. Neither group experienced any fading to speak of. In addition to intersubjectivity and calibrated assistance, however, there *was* a third factor that favored the CC groups. It wasn't fading, and it wasn't directly related

to scaffolding at all. It dealt with learning in multiple contexts and it is to this that we now turn.

   Learning in multiple contexts. This is the final section dealing with analysis that features distinctions between the PC and CC scaffolding. It will explain not only why, from my perspective, the CC wiki groups had superior performance, but also why that performance was largely attributed to a very strong showing on two questions in particular. Those dealt with submicroscopic representations of precipitation reactions, questions five and six on the CC posttest.

   As was briefly noted in the Results chapter, there was considerable concept overlap among three of the four chemical changes topics. For example, Topic 2 was primarily interested in the structure of a precipitate (i.e. an ionic solid). Students were expected to recognize the misconception that ionic solids exist as molecular pairs (they, in fact, exist as three-dimensional lattice structures). The overlap with Topics 1 and 4 comes not from that primary objective, but rather from a counter example. That is, for Topic 2a, although choice #2 was incorrect, the diagram represented what would amount to a correct understanding of Topics 1 and 4. Specifically, it represented how aqueous ionic compounds exist as independent ions. Recall from earlier, it was shown how the midpoint discussion between the teacher and the CC-2 group prompted Sofia to consider another way of describing "separated" ions. That discussion dealt with *Topic 1*. However, Sofia later applied what she learned from that discussion to her explanation of *Topic 2*. The teacher scaffolding for Topic 1, then, aided Sofia in understanding both Topic 1 and Topic 2.

   Topics 1 and 4 were also very similar. Topic 1 deals with aqueous solutions of

ionic compounds in general, whereas Topic 4 deals with aqueous solutions of ionic compounds that are involved in a precipitation reaction. In spite of the difference, they generally complement each other. The objective of Topic 1 is for students to understand the misconception that aqueous ionic compounds exist as molecular pairs of ions. The students need to understand this interpretation is incorrect, and that *aqueous ionic compounds exist as independent ions*. Similarly, the primary objective of Topic 4 is for students to understand that spectator ions, which originate from *aqueous ionic compounds, are independent ions* before and after the reaction.

Notice that when Topic 1 and 4 are distilled in a certain way, both focus on the fact that *aqueous ionic compounds are independent ions*. For Topic 4, CC-4 member Diego wrote about aqueous $NaNO_3$ that "it can be separated" (taken to mean the ions are independent of each other). For Topic 1, another CC-4 member Samuel wrote about NaBr that "the different elements separate from each other when they are in water" (also taken to mean the ions are independent of each other). Both students were describing the behavior of very similar ionic compounds, but in different contexts. Thus, there was considerable overlap between topics 1, 2, and 4 for the CC groups. By contrast, the four topics from the PC activity have much less in common conceptually.

Perhaps the primary reason the CC groups did so much better on questions five and six can be attributed to the different contexts in which the same underlying principle was presented. The focus on Topic 1 was the misconception that aqueous ionic compounds exist as molecular pairs of ions. In Topic 2, the primary objective dealt with the misconception that precipitates exist as molecule pairs of ions. For Topic 4, spectator ions were the focus. When learning a concept in different contexts "people are more

likely to abstract the relevant features of concepts and to develop a flexible representation or knowledge" (Bransford et al., 2000, p. 63; citing Gick and Holyoak). Therefore, by seeing and interacting with the submicroscopic representations of precipitation reactions in different contexts, CC students may have facilitated transfer from one school task (the wiki activity) to a similar task (the posttest). This phenomenon has been referred to as *near transfer* (Bransford et al., 2000).

That near transfer would occur in this case, however, assumes that students were actually engaged in *all* the related topics. We have already seen where peer editing was minimal and thus, it we focus on that alone, it would counteract this argument. However, we have seen evidence of other ways, aside from peer editing, in which CC students were "minds on" for multiple topics. As one example, recall CC-2 members Sofia and Isabella were quick to correct Santiago during their midpoint discussion when he suggested changing his "bunched together" explanation for the ionic solid representation in Topic 1. Although that was *his* original topic, the *girls* were the ones who corrected him. As another example, CC-4 member Camila recalled in her focus group how Diego's soccer image from *his* topic helped *her* understand spectator ions. In other words, CC groups demonstrated at least moderate levels of engagement across multiple topics. This fact, combined with the underlying concept being presented in different contexts, may account, in part, for the exceptional performance of the CC groups on questions five and six on the CC posttest.

Summary. Given the advantages the CC groups enjoyed in terms of intersubjectivity and calibrated support, and their opportunity to learn one fundamental underlying concept in different contexts, we can begin to make sense of their superior

performance relative to the PC group. We will now leave this analysis that has focused

on comparing the PC and CC groups, to begin one that takes a closer look at the

theoretical underpinnings that help us understand why the CC group was better able to

overcome a common misconception.

Overcoming misconceptions.   Why did the NI group generally retain the

misconception that aqueous ionic reactants exist as molecular pairs of ions? Why did

Gabriela believe the empty space between the nitrogen molecules must contain oxygen?

Why was the CC wiki group able to overcome the same misconception the normal

instruction group was not? This section will address these questions, beginning with the

first two.

Students have difficulty overcoming misconceptions "however much they conflict

with scientific concepts" (Bransford et al., 2000, p. 179). Both Vygotsky and Piaget offer

theoretical rationale for this dilemma. Thinking in concepts begins in adolescence

according to Vygotsky. The building blocks for these concepts are *complexes* which

represent a less abstracted form of a concept. Once they reach a developmental level in

which they can fully grasp concepts, Vygotsky suggests they don't completely discard

complexes (L. S. Vygotsky et al., 1994). Therefore, perhaps the normal instruction (NI)

students possessed a misunderstanding of the submicroscopic representations of

precipitation reactions before their lessons and, in spite of what they learned in the course

of NI, they were not able to abandon their "complex" level of understanding. Piaget

would likely support this assertion. Although he believed a child who reaches a

particular developmental stage does not ever revert to a prior stage, he did maintain that

"the more primitive structures of early stages" are not completely lost in later stages

(Driscoll, 2005, p. 194).

Therefore, whatever qualitative changes occur as individuals move through Vygotskian or Piagetian stages, it appears that remnants of prior stages persist. The fact that aqueous ionic reactants exist as independent ions was certainly covered in the NI classes. Jody noted in the teacher interview that she even "drew a bunch of pictures on the board for all classes" that represent how ionic compounds separate when dissolved. Furthermore, on the day the wiki group had their midpoint face-to-face discussions, NI students were assigned textbook problems asking them to write net ionic equations. Successful completion of these problems involves separating aqueous ionic reactants into separate ions. Therefore, in spite of having been taught the same concepts as the wiki group, the NI students were significantly less able to overcome the misconception. From a Vygotskian or Piagetian perspective, this might be due to misconceptions which originated in earlier developmental stages.

Unfortunately, the evidence in the current study does not permit us to make a strong assertion that these misconceptions indeed developed in earlier developmental stages. Nevertheless, we can still unpack the issue to a certain degree. Kelly et al. (2009) suggest that students might have trouble understanding the relationship between molecular equation symbolism and submicroscopic representations. For example, the molecular equation for a common precipitation reaction is $NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgCl(s)$. The fact that NaCl *looks* like a molecular pair in this equation is possibly too much for some students to get past, even though chemistry teachers emphasize that when NaCl is dissolved in water it is better represented as $Na^+(aq) + Cl^-(aq)$ because it actually exists, in that case, as separate ions. It is likely that when

students first encounter formulas of chemical compounds, say, in elementary school, they always see them represented as neutral, complete compounds ($NaCl$, $C_{12}H_{22}O_{11}$, H_2O, etc…). Perhaps it is at this time, in a concrete operational stage, when making associations among abstractions is not possible, they develop alternative conceptions of chemical symbolism that linger into adolescence.

We have also seen PC-2 member Gabriela get hung up on another misconception. She wrote on her wiki page that oxygen must be in the space between gaseous nitrogen molecules. This misconception that *something* must exist in the empty space between gas molecules is not uncommon. When 16-20 year olds in one study were asked "What is there between particles?", more than one-third responded with "vapour or oxygen" (Barker, n.d., p. 11; citing Novick and Nussbaum). This result, according to Novick and Nussbaum (1981), suggests students have difficulties with the particle model of matter when it conflicts with their "immediate perception" (p. 187). They continue by asserting these instances "present the greatest cognitive difficulty and are therefore least internalized" (1981, p. 187). In other words, what would be least internalized in this case is the correct interpretation that *nothing* exists in the empty space between gas molecules. As Novick and Nussbaum (1981) remind us, the maxim "nature abhors a vacuum" apparently applies to learners as well (p. 193).

Gabriela's *immediate* perception, which she confirmed in the focus group, was there must be *something* between the gas molecules (for her, that "something" was oxygen). Her preconception of matter as continuous, with no allowances for "empty space", might have led her to a level of *perceived* low cognitive conflict. Recall she was the one who was feeling overwhelmed as she read the teacher discussion forum feedback.

She expressed dismay with comments such as "Oh my Jesus!" and "This is giving me a headache". Therefore, for her, perceived low cognitive conflict may have served as a source of comfort. Then later, when the next teacher posting indicated "the last sentence you added about there being more oxygen in the gaseous nitrogen is incorrect", Gabriela never corrected the error (nor did any other group member). If understanding that the space between gas molecules really is *empty* causes the "greatest cognitive difficulty", then coming to grips with that, for Gabriela, might have meant taking her from her perceived low level of cognitive conflict to a higher level. This was likely a place she had no interest in going. She describes it in more ambiguous terms:

EO:	In the end, in your final explanation you left that [comment about oxygen] in there, even though in the final discussion posting, [the teacher] indicated it was wrong. Why didn't you ever fix that?

Gabriela:	I probably understood what she meant but I probably didn't know how to write it down. And I was probably confused.

EO:	Did you read the final posting?

Gabriela:	I believe so.

EO:	So you read it, but you were still not sure how to interpret it?

Gabriela:	Mmm hmm. Yes.

The emphasis here, for both the misconception that aqueous ionic reactants exist as molecular pairs, and for the one Gabriela demonstrated about not allowing for empty space, has been on the origins and persistence of the misconceptions. What this doesn't address, however, is why the wiki group might have been able to *overcome* the misconception about aqueous ionic reactants existing as molecular pairs. For this we will

again turn to Vygotsky and take a closer look at his interpretations of signs and tools.

Signs. From a theoretical standpoint, why was the wiki group able to overcome the misconception that aqueous ionic reactants exist as molecular pairs? Perhaps Vygotskian theories on signs can help us answer that question. For him, there were three types of signs, of which *symbolic* signs are the most abstract and also the most relevant to our discussion. Words are symbolic signs, their abstractness coming from the fact that the word "fire", for example, looks, smells, and sounds nothing like actual fire. Yet anyone with a minimal working knowledge of the English language knows what the word "fire" represents. Elemental symbols such as Na or Cl are also symbolic signs. The circular objects used to represent individual ions in questions five and six on the CC posttest (Appendix D) are as well. Vygotsky believed that higher order thinking corresponded to increased use and understanding of symbolic signs.

The wiki students, as a result of the activity, may have developed the most abstract understanding of the signs used to represent ions in precipitation reactions. It is this higher level of abstraction, then, that allowed them to make a greater number of associations. That is, just how a human can use the abstract word "fire" to readily make associations to other words in the language, even words that are seemingly unrelated (phone, blanket, water, etc…), chemistry students with a higher degree of abstracted understanding of chemical symbolism can better associate one symbol to another.

For example, assume for the moment that a fair amount of both wiki and NI students were able to correctly write an equation representing the dissociation of sodium chloride in water: $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$. We will even assume that both understood this represents the ions splitting apart when dissolved in water. The wiki

group, however, having a more abstracted understanding, more fully understood the true nature of how ions exist in aqueous solution. That is, they can associate, more so than the NI group, the dissociation equation shown above with the submicroscopic representations shown in questions five and six on the chemical changes posttest. Most importantly, they can associate both of those symbolic sign systems (the equation above and the images in questions five and six) with the true nature of how ionic react compounds exist in water.

Tools. If interacting with the submicroscopic representations of precipitations reactions was responsible for the better performance of the wiki group at overcoming misconceptions, it raises yet another question. If, instead of the wiki, students in the treatment group were asked to address the same issues with paper and pencil, would the results have been any different? That is, if treatment students were provided with all the same template content (same questions, same images, etc…), but it was presented on a piece of paper, would the treatment group have done just as well? We will assume identical face-to-face instruction from the teacher as well as the same amount of class time devoted to face-to-face small group work. Each student would have their copy of the assignment.

Vygotsky believed that "learners form, elaborate, and test candidate mental structures until a satisfactory one emerges" (2005, p. 387). Furthermore, this is facilitated by social interactions (Gnadinger, 2001). Certainly, students attempting this activity with paper and pencil could have fruitful face-to-face discussions. Then, whenever they had a "candidate mental structure" (i.e. an idea for how to execute the activity) they could jot down notes on their piece of paper and show it and discuss with

the group. Other group members could then evaluate what the first student suggested, and then perhaps cross out some text, and add some revised content (i.e. make some edits). If all this sounds archaic in today's technological world, imagine then that the students were doing this on a word processor. This would certainly facilitate editing. In this case, when the group adjourned the face-to-face session, they could email one another the document after making changes, such as what one does when using the Track Changes feature on Word. Using the word processor would also allow for pasted images and linked videos.

What the above alternative tool suggestions have in common, however, is they all fall short of what a wiki can accomplish if learners need to "form, elaborate, and test candidate mental structures". For Vygotksy, a tool was "something that can be used in the service of something else" (Driscoll, 2005, p. 251). The wiki itself can be thought of as a tool. Much more efficiently than a piece of paper, or a Word processing program, it allows for the back and forth required if social interactions are to play a vital role in cognitive growth.   In this study, the wiki group was able to "test candidate mental structures" by making their thinking visible in a much more convenient manner than a paper or word processor allows.

Consider that at 7:23 PM in the evening, CC-2 member Santiago posted a video on Topic 3. He did so after reflecting on the content originally posted by Isabella. In his focus group, he described how he saw a "video and like it was relating to what [Isabella had originally posted], so I posted it". He also added a considerable amount of text that accurately summarized the video. This included, "the video shows you that the starting mass is the same as the ending mass, even thoe [*sic*] there was a chemical reaction". He

goes on to write how this confirmed that atoms and mass were conserved. His description was not only accurate but it was also focused squarely on the primary objective. Later that evening, at 8:31 PM (presumably in a different location then Santiago), Isabella made three grammar and spelling corrections to Santiago's text. It seems unlikely that a paper and pencil activity, or even a Word document transmitted by email, would have as conveniently facilitated this collaborative knowledge building. Larusson and Alterman (2009) concur that "co-editing a [word processing] document requires much more coordination work" (p. 376).   Therefore, if a tool is "something that can be used in the service of something else" (Driscoll, 2005, p. 251), wikis can serve as the tool for collaborative knowledge building in place of more traditional tools that are less efficient.

Internalization of tools and signs. Vygotsky also suggested that cognitive development depends on sign and tool usage becoming internalized (Driscoll, 2005). There was evidence in the study that at least sign usage was. During her focus group, which occurred several weeks after the completion of the activity, CC-2 member Sofia recalled "I couldn't really find a video that people come together". Her explanation about the Lion King video representing when things "come together" demonstrates, almost two full months after the conclusion of the activity, that perhaps she has internalized the images (i.e. the signs) which represented the ions "coming together" to form a solid lattice (for that matter, this might also represent internalization of the wiki tool, as Sofia was able to recall an important detail of the Lion King video, which itself was embedded on the wiki).

Three weeks after the activity, Jody noted during the teacher interview that "the

class period that did the [chemical changes] wiki had a better understanding of just like what a solution looks like and even in their [precipitation reactions] lab reports". Therefore it seems that internalization of the chemical symbolism might have led to another example of near transfer, as students were able to apply what they learned from the wiki activity to another school assignment. Finally, the results of the posttest itself seem to indicate a degree of internalization. CC students exhibited superior performance on the questions involving submicroscopic representations of precipitation reactions without the benefit of any reference materials.

Summary. Student misconceptions demonstrated in this study may have originated in earlier developmental periods. The theories of both Vygotsky and Piaget suggest misconceptions might linger into more advanced developmental stages in spite of evidence students might see to the contrary. Wiki group students were described as better able to overcome misconceptions because they developed a more abstracted representation of chemical signs. Further, students who retained misconceptions might have done so because of an inability to modify immediate perceptions. Finally, the wiki itself, from the point of view of Vygotsky, can be seen as an effective tool for helping students develop these more abstracted understandings.

Limited student participation. This section will conclude the portion of the Discussion chapter devoted solely to the first research question. In a sense, I will now take a step back and look at the "big picture". That is, the one and only result that directly answered the first research question was that the wiki group did not perform significantly better than the NI group. The lack of peer editing has been mentioned several times already and, in my opinion, is largely responsible for the overall non-

significance. This section will take a closer look at that issue.

  Social negotiation. Classrooms based on the Piagetian model use instructional methods that "encourage peer teaching and social negotiation" (Driscoll, 2005, p. 215). Vygotsky would assert that it is primarily through conversation that student misconceptions become "explicit and accessible to correction" (Gnadinger, 2001, p. 28). We have seen that a constructivist approach, which has been attributed to both men, means "learners form, elaborate, and test candidate mental structures until a satisfactory one emerges" (Driscoll, 2005, p. 387), and that social interactions promote this (Gnadinger, 2001). Implicit in these descriptions is that the social negotiation that facilitates learning and development occurs frequently and effectively. Therefore, for a wiki activity to realize its full potential, student communication needs to be frequent and effective. Unfortunately, in this study, the former was missing and the latter was isolated. If we turn to Vygotsky for a moment, perhaps the explanation for this limited participation lies in the fact that his emphasis was not on formal educational settings, but rather the culture at large (L. S. Vygotsky et al., 1994). No better wiki represents the culture at large than Wikipedia.

  Wikipedia relies on the power of numbers and time. It has more than 13 million registered editors and countless other unregistered ones, all of whom enjoy almost complete anonymity (Adler, de Alfaro, Mola-Velasco, Rosso, & West, 2011). Almost no personal information is available to others, even for registered users (Hansen, Berente, & Lyytinen, 2009). It is also endlessly dynamic. There is unlimited time to draw upon the contributions of editors and to continually improve content. Hansen et al. (2009) suggest the conditions of unlimited number of contributors, along with unlimited time, contribute

to rational discourse. Their main context was that Wikipedia effectively supports "emancipatory" forms of communication. For our purposes, the point is that generally the conditions yield, over time, reliable information. This is especially true for science and technical articles, which are typically not subject to biases as are controversial social issues (O'Neil, 2010). Wikipedia also excludes the use of force (Hansen et al., 2009). Contributions to articles are completely voluntary. By just about anyone's standard, Wikipedia is a tremendously successful wiki.

Classroom based wiki projects, on the other hand, do not share these characteristics. They typically involve small groups of students and have limited time frames. They also have other modes of communication, with both peers and teacher. They are not limited to the wiki discussion forum, as are Wikipedia contributors. In a study evaluating collaborative behaviors in U.S. K-12 wikis, the researchers noted a limitation of the study was that their methods could not assess face-to-face collaboration (Reich, Murnane, & Willett, 2012b). The results of the current study suggest perhaps the most important difference, compared to Wikipedia, is the participants not only are not anonymous, but they likely see and interact with each other every day. Effective online collaboration has been describing as needing to build from "prior face-to-face working relationships" (Vallance et al., 2010, p. 20). I believe the emphasis on *working* relationship cannot be overstated. If, for example, students have not learned to *work* together, their familiarity that is based on having a strictly friendly relationship, might actually be a hindrance. As the results of this study demonstrated, students did not want to offend one of their classmates by editing their work. The anonymity enjoyed by Wikipedia contributors, on the other hand, likely results in greater participation.

Peer editing. The aversion to peer editing demonstrated in this study has been repeatedly described in the literature. Some students prefer independent work (Reich et al., 2012c). Other students may feel "aggressive attitudes and feelings of discomfort" at the thought of someone else editing their work (L. Lee, 2010, p. 261). Various wiki studies across multiple disciplines have consistently found that students are uncomfortable making edits to content originally contributed by another (Lazda-Cazers, 2010; L. Lee, 2010; Matthew et al., 2009). Although these studies reflect student attitudes for wiki activities in particular, it is not surprising they stem from more general social attitudes. Students are often concerned with "division of labor and social issues" (Rogoff, 1990, p. 163). Biology students working in collaborative groups during field studies, for example, preferred to maintain social harmony rather than engage in the open discourse required to create cognitive conflict (Anderson et al., 2009). To underscore this, in the study of wiki usage patterns in U.S. K-12 schools, collaborative student wikis were so uncommon they represented only 1% of a representative sample drawn from nearly 180,000 wikis (Reich et al., 2012c).

In this study, Sofia stated "you never know if they'll get mad at you" when referring to editing someone else's work. Luciana added, "I guess I get mad a lot when people change my wording". This comment was echoed by Daniela, who suggested "you get offended" when other's edit her contributions. Clearly, some of the same concerns expressed in the literature were plainly evident amongst these students. This is a dilemma teachers and educational researchers need to address. Complex communication and technology literacy have been described as fundamental 21st century skills (Reich et al., 2012c). It is hard to imagine students would be well positioned to develop these skills

when they are so skittish about collaborative editing, an emerging form of complex communication.

To overcome this, it is important for the teacher to discuss with students the "nature of…small cooperative groups" (Basili, 1988). This includes emphasizing how collaborative activities generally, wiki or otherwise, promote deeper understanding of content and help you learn to treat other's opinions with respect (De Lisi, 2002). It also entails spelling out how fellow team members can help you identify mistakes (Rogoff, 1990). Furthermore, it means also focusing explicitly on wikis. In a wiki study involving beginning college Spanish, the students themselves recognized the inherent roadblocks in the activity and asked for assistance in how to manage their peer-editing (L. Lee, 2010). All that being noted, the current study *did* all these things to varying degrees. The results suggest it wasn't sufficient. Student reflections in their focus groups, as well as evidence from the wiki history support this assertion. They all confirm that the scaffolding aimed at motivating students to enthusiastically embrace the nature of the activity generally failed.

I believe the shortcomings of this motivational scaffolding were a combination of degree and substance. In her wiki study, L. Lee (2010) suggested "the instructor should constantly monitor the editing process" to monitor student collaboration (p. 271). I believe this is critical, especially for students who are unfamiliar with collaborative projects generally, and wikis in particular. This study found that having a trial run that mimicked the study wiki activity was inadequate to create sufficient familiarity. Several students noted the trial run was helpful in getting them comfortable with the wiki tools (how to edit text, how to embed a video, etc…). However, it appeared to be inadequate

for laying a foundation for promoting unconstrained student participation, especially

when it comes to the peer editing process. Lund sheds light on why this may be the case

(Lund, 2008):

> Historically and institutionally, schooling has cultivated mostly an individual approach to writing (individual grades, exams), individual reproduction or problem-solving. Such an inheritance is not easily discarded or transformed. (p. 50)

If schooling, then, has cultivated an individual approach to learning, it follows that

expecting students to adapt to the complex, collaborative oriented communication

inherent in a wiki is not likely to change overnight, or even after a trial run of several

weeks. Therefore, teachers should have both realistic expectations when they introduce

such tools, and they should expect to have to "constantly monitor the editing process"

throughout the early stages of implementation.   The "early stages" is meant to imply at

least months, rather than days or weeks.

A second suggestion deals with systemic change. Successful wiki projects are

likely to take place in schools, or school districts, in which teaching the 21st century skills

of complex communication and technology literacy are ubiquitous. A student who has

had multiple knowledge building wiki projects in biology class as a sophomore is far

more likely to seamlessly transition into a similar activity for junior year Chemistry.

Student comments support the assertion that embracing the core values of collaborative

wiki work takes time. CC-2 member Isabella noted about peer editing that "sometimes

we would get mad at each other like when this person took out this thing" but she then

concedes she might eventually come to realize there was a useful and productive

rationale behind the edit. Echoing Isabella's sentiments, fellow CC-2 member Santiago

noted the activity was "fun. Especially once you get into it." His comment "once you get

into it" suggests, like Isabella, his *initial* reaction to what the activity entails was not so enthusiastic.

These two students were above average performers in the activity, and still were not ambitious peer editors (recall Isabella hadn't made any edits to CC-2, Topic 1). All this suggests that for students at-large, it might take systemic changes within an institution to transformatively shift student attitudes to the point where they embrace online collaborative work. When asked why he didn't post a question for the teacher on the discussion board, CC-4 member Tomas explained, "Cause we were kind of new at this and we didn't know if someone would see it or not so [we'd] rather just tell it directly rather than on the wiki". This suggests an institutional commitment to online collaborative learning would mean Tomas and his group would have fewer hesitations about posting questions on the wiki discussion board. He then would have had similar opportunities in numerous prior classes and would have few doubts the instructor was going to check his posting.

Summary. Some of the characteristics of Wikipedia that make it so successful, such as anonymity and unlimited time, do not exist for classroom based wiki activities. This is not at all meant to dismiss the potential benefits of educational wikis, but rather to remind us that transformative educational change is often a "slow-revolution" (Schweizer et al., 2003, p. 281). Therefore, not only do teachers need to make students aware of the benefits of collaborative wiki work, they also need to have reasonable expectations. The aversion to peer editing that many students possess, which has been exacerbated by years of individually-based school assignments, will not change over the course of one or two activities. In the early stages of implementation, it is especially worthwhile for teachers

to constantly monitor the progress of peer editing.

Summary (Research Question 1). The first research question asked if there is a difference in academic achievement between a wiki and NI group on selected concepts from the topics of bonding, physical changes, and chemical changes, when Latino high school chemistry students collaborate on a quasi-natural wiki project? The hypothesis was that the wiki (treatment) group, for all three activities collectively, would do significantly better than a normal instruction (control) group as measured by posttest scores. This hypothesis was not supported. The preceding discussion asserted that the primary reason for this was limited student participation. In particular, there was a considerable lack of peer editing. This was rationalized as a reasonable student response, considering that formal education for them has meant a decade or more of mostly individual assignments and assessments. Overcoming this will not occur in a limited timeframe or without concerted efforts across schools and districts.

However, the chemical changes wiki group did do significantly better than their respective control group. This was attributed, in part, to more effective distributed scaffolding in the form of promoting intersubjectivity and delivering calibrated assistance. In the CC activity, relative to PC, the teacher was more likely to withhold a critique of student creativity until after providing mostly unreserved positive feedback. This was said to foster intersubjectivity to a greater degree for the CC groups. For calibrated assistance, PC groups could have used additional or modified calibrated assistance that was aimed at addressing uneven levels of participation and lack of focus on the primary topic. The superior performance of the CC group was also described as resulting from the way in which wiki students interacted with the primary underlying

concepts. That is, they did so across multiple contexts. Finally, wiki students were said to have been better able to overcome misconceptions as a result of developing more abstracted representations of chemical signs.

Research Question 2

Research Question 2: What are the characteristics of distributed metacognitive scaffolding when Latino high school chemistry students collaborate on a quasi-natural wiki project?

Hypothesis 2: The teacher will be more effective than peers at facilitating metacognitive thinking in learners.

Results suggest the second hypothesis is supported primarily based on the abundance of teacher metacognitive scaffolding (MS), rather than necessarily its effectiveness. This study did not evaluate directly whether or not reflection took place, such as what might occur by monitoring student discussions and asking them to always verbalize their thoughts. Rather, instances were classified as metacognitive scaffolding if the teacher or peer support was intended to promote reflection or if it was likely to promote reflection (regardless of the intent). An example of the former would be a teacher discussion board posting, "Explain how your creative response to section 'b' ties in with your answer to section 'a'". The intent here is to get the student to reflect. An example of the latter would be when a student adds wiki content (text, image, video, etc…) that, based on evidence such as focus group data or subsequent wiki content, may have prompted another student to reflect. In that case, it's unlikely the intention of the first student was to stimulate reflection. Nevertheless, it may have had that effect. What this is getting at is the second hypothesis is supported, but not without two reservations.

First, reflection was not measured directly, and second, it was assumed that more abundant MS equates with more effective MS.

The discussion which follows will be divided into two major sections. First, we will look at the results from the two major categories of MS that had a considerably greater number of teacher occurrences, relative to peer. Those were metacognitive scaffolding – content knowledge (MS-CK) and metacognitive scaffolding – making connections knowledge (MS-MCK). Second, we will turn to the two forms of metacognitive scaffolding that had very little difference in relative abundance, metacognitive scaffolding – general goals knowledge (MS-GGK) and metacognitive scaffolding – strategy knowledge (MS-SK). In both cases, the one featuring more abundant teacher metacognitive scaffolding and the one not, I will begin with a brief review of the results, highlighting the major findings. That will be followed by a more detailed look at one vital shortcoming associated with each. In the case of MS-CK and MS-MCK, we'll discuss the almost total lack of peers posing a question for one another, and how that might be rectified. For MS-GGK and MS-SK, we'll turn our attention to MS-SK in particular. Results indicated almost no metacognitive scaffolding for strategy knowledge, from either teacher or peers. We will discuss how that too might be improved.

Abundant teacher metacognitive scaffolding (MS-CK and MS-MCK).

Review. This section features MS in which the instances of teacher MS was considerably greater than peer MS. This occurred for the MS-CK and MS-MCK categories and we'll begin with the former. Peers were found to use three means of delivering MS-CK. They often did so by adding *wiki content*. For example, the content

that CC-2 member Santiago posted on his page about "groups" of ions, was later edited to state "pairs" of ions by Sofia. His original text likely played a role by providing a template that prompted her reflection on what the primary topic was. Recall the misconception dealt with molecular *pairs* of ions. A second category of peer MS-CK was *posing a question*. An example is when Mariana asks her PC-1 partner Luciana, "Wouldn't it be an element because they're the same thing, they're not?". It is this category we will unpack in greater detail below. The limited number of questions posed by peers is taken to be a missed opportunity. Finally, *taking initiative* to lead a face-to-face discussion is the third example, such as Gabriela from PC-2 pushing Lucas to reconsider his Topic 4 explanation.

Teacher MS-CK was not only more abundant, but also more varied. Similar to peer MS-CK, *posing a question* was a category. In this case, however, it was more prevalent. This occurred either face-to-face during the midpoint discussion or by teacher post, such as "if you decide that answer to [was there conservation of atoms] is YES, then what does that tell you about the mass?". Another discernible category was *video explanation*, such as the teacher posting to PC-1 about the dry ice video, "Just make sure to add a brief explanation that ties in with the overall topic". *Sentence starters* (also referred to as *fill-in-the-blank*) were also fairly common. For PC-1 in Topic 4, the teacher posted, "because it has a mixture of helium atoms and chlorine (what goes here?)". The final category of teacher MS-CK was *look up definition*, such as when Jody asked Sofia and Isabella from CC-2 to look up the definition of precipitate. The teacher's intent in all four of these categories was to get students to reflect on their content knowledge.

In addition to the *posing a question* category which occurred in both peer and teacher MS-CK, they had something else in common. The evidence suggested both teacher and peer MS-CK had mixed results. That is, some of the occurrences of MS-CK appeared to successfully result in student reflection (as indicated by evidence from focus groups, face-to-face dialogues, and/or subsequent content added to the wiki), whereas others did not. This was true for all forms of MS.

Turning to the second form of MS which favored the teacher, we'll review metacognitive scaffolding – making connections knowledge (MS-MCK). Peers demonstrated only two types, the first being *creative connections*. More than once, this peer MS-MCK involved students sharing ideas either face-to-face, or by phone or text message, about what would be the best video or image to connect to the topic. An example is when Sofia and Isabella texted and called each other and eventually decided on using the Lion King video. The second category was *real-world connections*. Recall in the midpoint discussion of the dry ice video, Daniela was the first to point out, "Now we know what they use in the movies".

By contrast, teacher MS-MCK was characterized by three distinct categories. *Creative connections* was seen, as it was for peers, such as when the teacher encouraged creativity to CC-2 when they had yet to add content, "Don't be afraid to be creative. Doesn't have to be perfect". *Creative shortcomings*, on the other hand, was a creativity oriented category distinct from peers. In this case, the teacher might offer the following comment about creative content, "…like most analogies, it seems to me to have at least one flaw", hoping the group would think more deeply about the connections they were proposing. The last category of teacher MS-MCK was *activity connections*. In this case,

Jody would remind students to consider how to link section "b" of their topic to section "a".

Of all the preceding results, the one that was most notable was the lack of *posing questions* exhibited by peer MS-CK. It was notable because it was so infrequent, and improving on that result might hold considerable promise if distributed scaffolding is to realize its full potential in promoting metacognition. Few things prompt reflection as overtly as a direct question. For that reason, we will analyze this in greater detail.

Posing questions. Ciardiello (2000) suggests "when students ask questions of their peers, the nature of the discourse is much more frequent, open, egalitarian, and spontaneous" (p. 220). When dialogue is "frequent, open, egalitarian, and spontaneous" it certainly holds promise as a strategy that is educationally fruitful. For our purposes, a fruitful discussion is one that stimulates reflection. Based on the finding that metacognitive scaffolding from peers in the form of *posing a question* was rare, the lack of peer questioning thus represents an untapped resource in a collaborative project, wiki-based or otherwise. Choi et al. (2005) notes "when learners receive critical and personalized questions from their peers, those interactions should prompt deeper reflection on and revision of their own knowledge" (2005, p. 488). I suggest that posing a question is a critical form of metacognitive scaffolding. As opposed to instances in which content posted on a wiki page by one student prompts another student to reflect, a well-designed question that is "personalized" and directed at a particular individual is less likely to be overlooked. It is also more likely to direct a student's attention to the primary objective. As Rosenshine, Meister, and Chapman (1996) assert, "The act of composing questions focuses the student's attention on content" (p. 181).

Increasing the frequency of either face-to-face or discussion forum peer questions is not without its obstacles. Peers are often more concerned with finishing a project than learning from it (Rogoff, 1990). They also tend to be more concerned than adults with "division of labor and social issues" (p. 163). Furthermore, they generally prefer to maintain social harmony at all costs, as we saw in the example of biology students who avoided open discourse (Anderson et al., 2009). Perhaps peer-generated questions might be seen, from the students' point of view, as potentially promoting social barriers. This does not need to be the case, however. In fact, a carefully worded question designed to influence behavior, in lieu of giving a direct order, is seen in business circles[23] as good leadership skills (Carnegie, 2009). Still, even students who are willing to ask more metacognitively oriented questions would not necessarily know how to do so. They might need interventions to assist them. Ciardiello (2000) asserts, "Student-question generation is not a natural by-product of subject-matter acquisition, seeing it instead as a specific learning skill that must be taught" (p. 217).

Therefore, training students to generate metacognitively oriented questions seems necessary. Two such examples of how this might be done will be offered here. The first is described as a "peer-questioning scaffolding framework" intended to facilitate metacognition in online discussions. It was described in the context of a study from a college online course on turfgrass management (Choi et al., 2005). One student would post a message related to course content. The second student would then read the posting, but, before replying, was instructed to consider various options for composing

---

[23] Dale Carnegie Training is found in all 50 of the United States and in over 80 countries around the world. Approximately 8 million people have completed the training. Most local franchises in the U.S. are accredited by the Accrediting Council for Continuing Education and Training (ACCET) which is recognized by the U.S. Department of Education (Dale Carnegie Training, 2013).

questions in response to the first student's posting. These options, designed by the researchers, were presented to students in the form of questioning tips, generic examples, and specific examples. For instance, a generic example would be "could you please explain it more" or "What did you mean by the term…?" After considering the options, the second student would then compose and post a question intended to promote metacognition in the first student.

Results suggested the questioning framework improved the frequency of peer-generated metacognitive questions. However, it was not demonstrated that they improved the quality of the questions nor the outcomes on a content oriented posttest. In spite of these qualified results, I believe such a technique is worth considering for a wiki activity, for three reasons. First, in the Choi et al. (2005) study, the frequency of the peer-generated questions was significantly greater in the treatment group, as was just noted. In the current study, the major difference between teacher and peer MS-CK and MS-MCK was a matter of frequency. Therefore, if implementing a questioning framework increased the abundance of peer MS-CK and MS-MCK, that alone makes it worthwhile. We would assume that more frequent MS-CK in the form of peer questions, over time, would correlate with more effective metacognitive scaffolding.

Second, a blended wiki activity such as the one from the current study (i.e. some online and some face-to-face) differs from the characteristics of the fully online class from Choi et al. (2005). Therefore, it is possible that a questioning framework would work better in a face-to-face environment where students wouldn't have to also overcome uneasiness with an unfamiliar online educational tool. Third, the Choi et al. (2005) study demonstrated considerable variability in terms of the extent to which the treatment group

utilized the prompts. In interviews, some students indicated they had trouble posting

their peer metacognitive question because the first student had posted their original

message so late. Also, they had trouble generating questions, in spite of the framework,

because they felt like their content knowledge wasn't strong enough. Both of these

issues, late original postings and student lack of confidence in their own content

knowledge, were also factors in the current study. Therefore, they cannot be dismissed.

However, they also don't preclude the possibility that a questioning framework could be

effective under the right circumstances. For example, as emphasized above, it may take

time (several or more wiki activities) before students become comfortable using them

effectively.

A second peer question-generating "training" procedure also involved a form of

question prompts. Rosenshine et al. (1996) reviewed well-controlled interventions.

Although the intent of the interventions was self-questioning, there is no reason the same

procedures couldn't be applied in a social context (i.e. one student posting a question for

another). The questioning strategies were described as "procedural prompts" that "supply

the student with specific procedures or suggestions that facilitate completion of the task"

(Rosenshine et al., 1996, p. 29). Five types of prompts were identified from the various

studies, one of which will be discussed here. These were referred to as *generic question

stems and generic questions*. Examples of generic question stems included "How are …

and …alike?" and "What is the main idea of…?" Generic question examples were "How

does this passage or chapter relate to what I already know about the topic?" and "What is

the main idea of this passage or chapter?"   These same prompts could be used in a wiki

activity to aid students in composing metacognitive questions for their peers.

As a reminder, question stems and questions similar to these were used in the current study. As one example, there were fill-in-the-blank questions such as "Also when (blank) is aqueous it means that its totally separated. What goes in the blank? (hint: it's a specific type of compound)". The point for the moment, however, is not to consider the teacher's questions as metacognitive scaffolding, but rather as a way of teaching students to generate their own metacognitive questions. Of course, one way of doing this is for the teacher to model the use of such questions, as Jody did. However, that alone is likely too subtle. More explicit training is necessary. Perhaps adding peer metacognitive questioning as a rubric category is an option. This could be combined with providing students with the question prompts.

At this point, it is worthwhile to reflect briefly on an important difference between the question stems from the Rosenshine et al. (1996) review, and most of the questions from the current study. In the case of the latter, the questions tended to be more specific. They were less generic than the generic question stems and generic questions described by Rosenshine et al. (1996). For example, the teacher postings in our case were more detailed. Consider the following teacher post to PC-1, Topic 2, which represents just a portion of the entire posting:

> I see a couple problems however. Remember, this topic deals with conservation of matter and that hasn't been fully addressed yet. To explain whether or not there was conservation of matter going from liquid nitrogen to gaseous nitrogen you need to address 1) Was there conservation of atoms? And 2) Was there conservation of mass?. If the answer to those two questions is yes, then there was conservation of matter.

Now contrast that to a much more generic question, not from the current study, "What is the main idea of this page?" Although we provided the wiki students with much greater detail, more is not necessarily better. It might make the scaffolding less effective.

Compared to students using directed (i.e. more detailed) metacognitive prompts, middle school students who utilized generic metacognitive prompts demonstrated "more coherent scientific thinking" (Wu, 2010, p. 24; citing Davis).

How might these generic question prompts have worked in our wiki activity? Students could have been provided with a generic prompt such as "How are… and …alike?" This particular prompt would have fit well with the creative aspect of the activity. Student's creative content often failed to link explicitly to the primary objective of a wiki page. Therefore, the prompt "How are…and…alike?" might lead to a peer generated metacognitive question "How is the Lion King video like the three-dimensional lattice structure of a precipitate?" Results also indicated students often failed to elaborate on the shortcomings of their analogy. Therefore another possible prompt could be "How are…and …*different*?" This might then lead to the peer metacognitive question, "How is the Harlem Shake video different from dissolved ionic compounds?"

Summary. Results of this study demonstrated that peers rarely pose metacognitive questions for their fellow students. Therefore, two methods for training students to generate such questions were discussed, described as a questioning framework and the other as question prompts. It is important to emphasize that while such frameworks and prompts might certainly benefit the student who composed a metacognitive question from them, and the person to whom the question was delivered, they also have more long term aims in mind. That is, they are designed to help students internalize these procedures so scaffolding would not be required in the future. Recall Jody's comments that students often lack the confidence to explain the concepts to one

another. Therefore, this suggests training students to post metacognitive questions for peers is perhaps an ambitious task. Perhaps the key lies in making it clear they don't need to be perfect. As Ciardiello (2000) notes, "Teacher must foster 'authentic' student questions in which the questioner does not know the answer and tentative responses are valued" (p. 220).

Infrequent teacher and peer metacognitive scaffolding (MS-GGK and MS-SK).

Review. Infrequent scaffolding was demonstrated for the major categories metacognitive scaffolding – general goals knowledge (MS-GGK) and metacognitive scaffolding – strategy knowledge (MS-SK). Although I will begin by briefly reviewing key findings, the lack of both teacher and peer MS-GGK and MS-SK is perhaps the most significant result. One category of *rubric reflection* emerged for peer MS-GGK. This generally involved students suggesting how many points to award a particular topic as part of their self-assessment, such as PC-1 members Luciana and Mariana did when considering the images of friends parting ways in Topic 1. For teacher MS-GGK, there were two categories. *Rubric reflection* was one. This took the form of the teacher highlighting key aspects of the rubric during the introduction day whole class presentation. These were rubric criterion such as the need for each student to make one significant edit to all topics not originally assigned to them. The second category was *learning to collaborate*, which was manifested by Jody spelling out the benefits of 21st century skills, also done on the introduction day.

Peer MS-SK was also limited to one category, *increase effort*. Gabriela was employing this when she emailed the other members of PC-2 the night before the

midpoint day. Her objective was to encourage them to get their assignment done before the deadline. For our purposes, we extend her objective to also mean that her partner Lucas read her email, and subsequently reflected on how the deadline was approaching and what he needed to do about it. Teacher MS-SK was more frequent than peer, but not much so. The first of two categories was *trial run reflection*. As part of their catalyst question (that is, the question on the board when students come to class each day), students were asked "What went well?" for the trial run and "What does your group need to do better to improve this time?" *Increase effort* was the second category. Generally this came in the form of a discussion forum posting. Both PC and CC groups received postings such as "We NEED to get this going! Let me know how I can help!".

The most notable results here is the lack of MS-SK, from both the teacher and peers. Proceeding under the assumption that it is vital for a student to know what to do once they recognize a knowledge gap, we will now take a closer look at metacognitive scaffolding that focuses on strategy knowledge. As part of our analysis, I will suggest ways in which MS-SK could have been improved.

Metacognitive scaffolding - strategy knowledge.

> Working together to achieve a common goal produces higher achievement and greater productivity than does working alone. This is so well confirmed by so much research that it stands as one of the strongest principles of social and organizational psychology (D. W. Johnson & Johnson, 1999, p. 71).

To the extent that Johnson and Johnson's assertion is valid, it suggests collaborative work is so clearly beneficial that it is critical to have the proper strategies to realize its potential. Ironically, one such strategy is the ability to thoughtfully reflect on your strategies. In a study of college foreign language distance learners, White (1999)

emphasizes how a big part of metacognitive reflection is "strongly directed toward a concern about how best to approach the learning units, and once underway, *how best to proceed*" (p. 44; italics added). Such reflection, dealing with "how best to proceed", can be aided by both teacher and peer MS-SK. Since results from the current study indicated there was only bare minimum MS-SK for both teacher and peer, this section will focus on ways in which it could have been increased and improved. Results from this study also indicated that two areas where students struggled were 1) participation levels and 2) focusing on the primary objective. Therefore we will take a closer look at both teacher and peer MS-SK in the context of peer editing and shifting student focus to the primary objective.

In doing so, we'll generally feature what the teacher's role is. It seems apparent the teacher would need to take the lead. As we've seen before, adults have been shown to "promote more advanced planning strategies…and elicit greater participation" then child partners (Driscoll, 2005, p. 258; citing the work of Radziszewska and Rogoff). In a study of Australian Year 11 chemistry students, two-thirds suggested their intervention strategy of using a construction metaphor to aid metacognition "could easily be discarded if it were not for the teacher's persistent reference to it" (Thomas & McRobbie, 2001, p. 254). Therefore, improving student's collaboration strategies, as well as their ability to reflect on those strategies, is something that generally needs to begin with the teacher.

One simple way in which teacher MS-SK can be improved is by increasing the frequency with which it occurs. An area in which it could have proven beneficial in the current study is by prompting students to reflect on the importance of focusing on the primary objective. How would this type of metacognitive scaffolding look? It would

mean that some of the questions posed by the teacher should be framed in a manner that is more intended to have the students reflect on general strategy, rather than on specific content (this isn't at all to say one is less important than the other). For the PC-1 group, for example, as they watched the dry ice video, the teacher might have interjected in one of two ways. First, she could say, "What does this tell you about whether or not substances decompose when they turn into a gas?". This is an excellent reflective question that focuses on content knowledge. In other words, it is MS-CK. Questions like this should certainly remain. The point is to include MS-SK into the mix from time to time. An alternative way in which the teacher might have interjected would be to say, "Have you considered yet how this applies to the primary objective of this topic?" That question is subtly, but not insignificantly different. It is intended to call student's attention to a general strategy. That is, to ensure the group remains focused on the primary objective.

Unfortunately, large class sizes often make it difficult for the teacher to ask these questions of every group in a timely manner (Wu, 2010). Distributed scaffolding can help alleviate this dilemma. That is, the MS-SK can be distributed amongst peers as well. As we have seen in this study, this is not likely to happen by itself. As a result of years of largely independent work, students are not accustomed to such roles. They don't realize the benefits of needing "to describe what member actions are helpful and unhelpful and make decisions about what behaviors to continue or change" (D. W. Johnson & Johnson, 1999, p. 71). The teacher then still needs to take the lead. In this case, however, it is manifested in assigning roles to group members to perform various tasks. This is accomplished by establishing what Johnson and Johnson (1994) call "clearly perceived

positive interdependence" (p. 33).

One way the teacher can structure positive interdependence is referred to as *positive role interdependence* (R. T. Johnson & Johnson, 1994, p. 34). In this case the teacher assigns "complementary and interconnected roles that specify responsibilities" (1994, p. 34). Roles might include "reader, recorder, checker of understanding, encourager of participation, and elaborator or knowledge" (1994, p. 34). For a collaborative wiki project, in particular one such as the current study that suffered from limited time focused on the primary objective, the teacher could assign a *checker of understanding*. One thing the checker could be instructed to do is periodically ask questions that amount to MS-SK to see if the group is focused on the task. Since the teacher has difficultly monitoring all groups, she can make a blanket reminder to the whole class, such as "Checkers, within five minutes, make sure to assess if your group members are focused on the primary objective".

Encourager of participation is another role that would have proved useful. This might amount to something akin to what Gabriela did for PC-2. Recall how she checked the wiki for member progress the night before the midpoint deadline. She then sent an email to group members encouraging them to make their contributions. An encourager of participation would have also helped during the face-to-face discussions. Instances where all three or four members of a group were engaged in the same discussion, huddled around the same computer, were rare. Generally it was one or two students on one computer and one or two students on another computer, with limited dialogue between the pairs (and often limited dialogue within the pairs). An encourager of participation could be responsible with making sure everyone is not only focused on the primary

objective but they are also working on it collaboratively. Stated another way, in a manner that frames it in terms of metacognition, the encourager of participation administers MS-SK with the hope it aids group members in internalizing the habit of reflecting on strategies. In this case, it would be the strategy of making sure all group members are fully participating.

These and other collaborative oriented roles such as *checker of understanding* and *encourager of participation* will not easily be adopted by students, especially those who lack confidence in both content and social skills. As noted earlier, the complex communication associated with 21st century skills, if it is to be embraced by students, will likely require patience and persistence on the part of the teacher as well as a concerted effort throughout the entire school or district. Even then it might be necessary to keep in mind a *preparation for future learning* (PFL) mindset (Bransford & Schwartz, 1999). That is, although gains in chemistry knowledge or collaborative skills might not be immediately apparent during a high school collaborative wiki project, the exercise may have planted the seeds for future success in the "knowledge-rich environments" of the 21st century (1999, p. 68). As Bransford and Schwartz (1999) assert, employability in the new millennium does not mean having learned everything before starting the job. Rather, it means being open and able to learn on the job and "make use of resources (e.g. texts, computer programs, colleagues) to facilitate this learning" (1999, p. 68). These are exactly the types of PFL skills a collaborative wiki project teaches.

Summary. As conceived in this paper, metacognition entails *recognizing knowledge gaps* and *knowing what to do* about those gaps. This section has focused on the latter. Distributed scaffolding in the form of metacognitive scaffolding – strategy

knowledge (MS-SK) can help learners reflect on knowing what to do. Both teacher and peer MS-SK was infrequent in the current study. Therefore, it was necessary to consider ways of rectifying that. Suggestions for accomplishing this were described as beginning with the teacher. One option is for them to be conscious of how they phrase questions for students, making sure to ask those that promote reflection on strategy as well as content. Further, the teacher can facilitate additional peer MS-SK by establishing positive role interdependence in the classroom. That is, by assigning roles to students such as *checker of understanding* and *encourager of participation*, and by exhibiting patience as students become accustomed to these unfamiliar roles, the potential of distributed MS-SK can be more fully realized.

Summary (Research Question 2). The second research question asked what are the characteristics of distributed metacognitive scaffolding when Latino high school chemistry students collaborate on a quasi-natural wiki project? The hypothesis that the teacher would be more effective at promoting metacognitive reflection in students was supported. However, it was so under the assumption that more frequent necessarily meant more effective.

Two forms of metacognitive scaffolding, MS-CK and MS-MCK, had considerably greater occurrence for the teacher than for peers. This result was unpacked to reveal that peers rarely posed metacognitive questions, of any sort, for their fellow students. Since students asking questions of each other often promotes "open" and "egalitarian" dialogue (Ciardiello, 2000, p. 220), suggestions were offered to improve the frequency and quality of peer metacognitive questions. These focused on providing students with various types of question prompts.

Contrary to the findings for MS-CK and MS-MCK, the other two forms of metacognitive scaffolding, MS-GGK and MS-SK, had infrequent teacher and peer occurrences. Because strategy knowledge was considered to have outsized importance, suggestions were offered on how the frequency of MS-SK might be improved. Teachers, it was recommended, who might be inclined to disproportionately offer MS-CK, should remember to phrase metacognitive questions in a manner that also prompts reflection on strategies. Peers might improve their MS-SK by being assigned roles such as checker of understanding and encourager of participation, both of which promote positive role interdependence.

Study Limitations

Quasi-experimental designs are intended to evaluate interventions when random assignments are not possible. They aim to establish causality between a treatment and an outcome (Harris et al., 2006). Any interpretations of causality from the current study need to be viewed with caution, however. Like all quasi-experiments, the lack of randomization is a threat to internal validity (Patten, 2012). Therefore, alternative explanations for the results need to be considered. The threat to internal validity was minimized, however, by rotation of treatment and control assignments such that each intact group served as wiki group once and control group twice.

Recommendations for Future Research

This study concluded that higher degrees of intersubjectivity were fostered in the CC groups (relative to PC). As a result of the nature of the teacher feedback on their creativity, feedback that delayed skeptical or critical comments, CC students were said to

experience a greater sense of task ownership than did the PC students. Due to the highly interpretive nature of the analysis, however, this result is more hypothesis-generating than conclusive. Therefore, a study is needed that more directly evaluates intersubjectivity. Rose (2004) assessed intersubjectivity by comparing the online dialogue in two group styles: cooperative and collaborative. In that case, learner perceptions of intersubjectivity were evaluated with a self-reported survey developed by the researcher. An example of a survey question was "My teammates and I reach a common understanding about important issues" (2004, p. 76). This method, too, has its limitations as it relies on self-report data. However, a wiki study that triangulates intersubjectivity survey data with other data sources, such as those used in the current study, might prove especially informative.

Statements were made in this study about levels of cognitive conflict experienced by students. This also needs to be evaluated more directly. One option is a study modeled after Moskaliuk et al. (2009), described in the literature review. In that case, students who had almost no prior knowledge of schizophrenia were asked to read a variety of short pamphlets. After doing so, they were presumed to possess equivalent knowledge on the subject. Wikis were then prepopulated with content to produce three conditions. The low incongruence condition had key points from all the pamphlets, the medium condition from some of the pamphlets, and the high incongruence condition from none of the pamphlets (i.e. the pages were blank). Subjects had the pamphlets to refer to during the two hour period in which they were expected to build their wikis. There was no collaboration during this wiki building period, thereby removing the confound of peer editing aversion. Such an experimental design could work well for a

high school chemistry class. Students in that case also generally have limited prior knowledge of the subject (as was demonstrated by the very low pretest scores). Three conditions could be established as they were in Moskaliuk et al. (2009). A potential confound with such an experiment, however, is that even after reading the pamphlets, and having them to refer to, there is a good possibility that all students would not truly have the same knowledge level to begin with. This equivalency might need to be established with a pretest as it was in the current study.

Fading was not observed in the current study. Therefore, developing a mechanism for incorporating fading, and then evaluating its effectiveness is potentially beneficial. In a study with high school students learning electrical circuit analysis, the impact of static versus adaptive fading was evaluated (Reisslein, Reisslein, & Seeling, 2006). In the static fading group, responsibility was transferred to the learner at fixed intervals. The adaptive fading group, on the other hand, assumed greater responsibility only after correctly solving a problem. The treatment was delivered through a computer-based learning environment. Results indicated the adaptive fading group significantly outperformed the static fading group on both retention and transfer. Considering there was no fading in the current wiki study, implementation of any fading scheme would be worth evaluating and perhaps an adaptive one in particular. Collaboratively developing a wiki, however, is considerably different than independently solving quantitative electrical circuit problems. Perhaps, to reduce the burden on the instructor, an encourager of participation might be designated. The teacher might give this student brief training on how to monitor group members' progress, such as through the wiki history. The student would also be provided with straightforward benchmarks for evaluating student

participation, guidelines that amounted to an adaptive fading schedule for encouraging participation.

Conclusion

The general purpose of this study was to evaluate a wiki-based instructional intervention to help reduce the White-Latino achievement gap in science. Results suggested wikis can, at times, be effective tools for helping Latino students improve their understanding of abstract and conceptually difficult chemistry concepts. When implemented in a manner that approached faithful execution of the distributed scaffolding model, wiki students outperformed a normal instruction group in understanding, and overcoming a common misconception of, submicroscopic representations of precipitation reactions. This result was aided by framing the activity such that students had the opportunity to engage the same underlying concept in multiple contexts.

However, as with most instructional methods, when fidelity of implementation was poor, so were the results. Students' aversion to peer editing and content-oriented online communication, as well as their unfamiliarity with posing questions for one another, obstructed their full engagement with the activity. After a decade or more of an individualistic approach to learning, many high school and college students are not yet comfortable with the collaboration inherent in a wiki activity. Thus, further research is needed to evaluate the full extent to which wikis can help reduce the White-Latino achievement gap, and the degree to which they hold considerable promise in preparing students more generally for the complex communication and technology literacy of the 21st century. It was suggested that perhaps not until school wide and district wide adoptions occur, are wikis likely to contribute to the transformative use of computers in

schools.

BIBLIOGRAPHY

ABC News. (2013). What is this "Harlem Shake" thing anyway? Retrieved July 14, 2013, from http://abcnews.go.com/ABC_Univision/Entertainment/harlem-shake-thing/story?id=18488615#.UeNVlm1r5CI

Achieve, I. (2013). Conceptual shifts in the Next Generation Science Standards Retrieved August 28, 2013, from http://www.nextgenscience.org/sites/ngss/files/Appendix%20A%20-%204.11.13%20Conceptual%20Shifts%20in%20the%20Next%20Generation%20Science%20Standards.pdf

Adler, B., de Alfaro, L., Mola-Velasco, S., Rosso, P., & West, A. (2011). Wikipedia vandalism detection: Combining natural language, metadata, and reputation features Retrieved September 18, 2013, from http://repository.upenn.edu/cgi/viewcontent.cgi?article=1494&context=cis_papers

Alber, M. (2001). Creative writing and chemistry. *Journal of Chemical Education, 78*(4), 478. doi: 10.1021/ed078p478

Alyousef, H. S., & Picard, M. Y. (2011). Cooperative or collaborative literacy practices: Mapping metadiscourse in a business students' wiki group project. *Australasian Journal of Educational Technology, 27*(3), 463-480.

Anderson, D., Thomas, G. P., & Nashon, S. M. (2009). Social barriers to meaningful engagement in biology field trip group work. *Science Education, 93*(3), 511-534.

Animoto Inc. (2013).   Retrieved March 12, 2013, from http://animoto.com/

Aron, A., Aron, E., & Coups, E. J. (2006). *Statistics for psychology* (4th ed.). Upper Saddle River, N.J.: Pearson Education.

Azevedo, R., Cromley, J. G., Winters, F. I., Moos, D. C., & Greene, J. A. (2005). Adaptive Human Scaffolding Facilitates Adolescents' Self-Regulated Learning with Hypermedia. *Instructional Science: An International Journal of Learning and Cognition, 33*(5), 381-412.

Barker, V. (1995). *A longitudinal study of 16-18 year old students' understanding of basic chemical ideas.* (Doctoral dissertation). ProQuest Dissertations & Theses database. (C505706)

Barker, V. (n.d.). Beyond appearances: Students' misconceptions about basic chemical ideas Retrieved August 6, 2013, from http://modeling.asu.edu/modeling/KindVanessaBarkerchem.pdf

Basili, P. A. (1988). *Conceptual change strategies within cooperative groups of community college chemistry students: An experiment.* (Doctoral dissertation). ProQuest Dissertations & Theses database. (8818357)

Berlyne, D. E. (1960). *Conflict, arousal, and curiosity*. New York,: McGraw-Hill.

Bertholdo, S. (2006). Teacher puts chemistry into motion with poetry Retrieved July 11, 2012, from http://www.theacorn.com/news/2006-12-28/Schools/Teacher_puts_chemistry_into_motion_with_poetry.html

Biehler, R. F., & Snowman, J. (1986). *Psychology applied to teaching* (5th ed.). Boston: Houghton Mifflin.

Bornstein, M. H., & Bruner, J. S. (1989). *Interaction in human development*. Hillsdale, N.J.: L. Erlbaum Associates.

Bransford, J., Brown, A. L., Cocking, R. R., & National Research Council (U.S.). Committee on Developments in the Science of Learning. (2000). *How people learn: Brain, mind, experience, and school*. Washington, D.C.: National Academy Press.

Bransford, J., & Schwartz, D. (1999). Rethinking transfer: A simple proposal with multiple implications. *Review of Research in Education, 24*(1), 61-100. doi: 10.3102/0091732x024001061

Bruning, R. H., Schraw, G. J., Norby, M. M., & Ronning, R. R. (2004). *Cognitive psychology and instruction* (4th ed.). Upper Saddle River, N.J.: Pearson/Merrill/Prentice Hall.

Butler, K. A., & Lumpe, A. (2008). Student use of scaffolding software: Relationships with motivation and conceptual understanding. *Journal of Science Education & Technology, 17*(5), 427-436. doi: 10.1007/s10956-008-9111-9

Carbon-dioxide-crystal-3D-vdW.png. (n.d.).   Retrieved September 18, 2013, from http://upload.wikimedia.org/wikipedia/commons/6/64/Carbon-dioxide-crystal-3D-vdW.png

Carnegie, D. (2009). *How to win friends and influence people*. New York: Simon and Schuster.

Çentıngül, İ., & Geban, Ö. (2011). Using conceptual change texts with analogies for misconceptions in acids and bases. *Hacettepe University Journal of Education, 41*, 112-123.

Chaiklin, S. (2003). The zone of proximal development in Vygotsky's analysis of learning and instruction. In A. Kozulin, B. Gindis, V. S. Ageyev & S. Miller (Eds.), *Vygotsky's educational theory in cultural context* (pp. 39-63). UK ; New York: Cambridge University Press.

Chang, R., & Cruickshank, B. (2005). *Chemistry* (8th ed.). Boston: McGraw-Hill.

Chemistry concepts: Conservation of mass/energy. (2009).   Retrieved September 18, 2013, from http://www.youtube.com/watch?v=J5hM1DxaPLw&feature=player_detailpage

Choi, I., Land, S. M., & Turgeon, A. J. (2005). Scaffolding peer-questioning strategies to facilitate metacognition during online small group discussion. *Instructional Science, 33*(5-6), 483-511. doi: 10.1007/s11251-005-1277-4

Ciardiello, A. V. (2000). Student Questioning and Multidimensional Literacy in the 21st Century. *Educational Forum, 64*(3), 215-222.

Cloonan, C. A., & Hutchinson, J. S. (2011). A chemistry concept reasoning test. *Chemistry Education Research and Practice, 12*(2), 205-209.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155-159.

Cole, D., & Espinoza, A. (2008). Examining the academic success of Latino students in Science Technology Engineering and Mathematics (STEM) majors. *Journal of College Student Development, 49*(4), 285-300.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser*. Hillsdale, NJ: L. Erlbaum Associates.

Costu, B., Ayas, A., & Niaz, M. (2010). Promoting conceptual change in first year students' understanding of evaporation. *Chemistry Education Research and Practice, 11*(1), 5-16. doi: 10.1039/c001041n

Cress, U., & Kimmerle, J. (2008). A systemic and cognitive view on collaborative knowledge building with wikis. *International Journal of Computer-Supported Collaborative Learning, 3*(2), 105-122.

Cuban, L. (2001). *Oversold and underused: computers in the classroom*. Cambridge, MA: Harvard University Press.

Cummings, R. E. (2008). What was a wiki, and why do I care? In R. E. Cummings & M. Barton (Eds.), *Wiki writing : collaborative learning in the college classroom* (pp. 1-16). Ann Arbor: Digital Culture Books, an imprint of the University of Michigan Press and the University of Michigan Library.

Dale Carnegie Training. (2013). About Us Retrieved August 5, 2013, from http://www.dalecarnegie.com/about_us/

Davis, E. A. (2003). Prompting middle school science students for productive reflection: generic and directed prompts. *The Journal of the Learning Sciences, 12*(1), 91-142. doi: 10.2307/1466635

De Lisi, R. (2002). From marbles to instant Messenge (TM): Implications of Piaget's ideas about peer learning. *Theory Into Practice, 41*(1), 5-12. doi: 10.1207/s15430421tip4101_2

Delpit, L. D. (2006). *Other people's children : cultural conflict in the classroom*. New York: New Press : Distributed by W.W. Norton.

DeVries, R. (2000). Vygotsky, Piaget, and Education: a reciprocal assimilation of theories and educational practices. *New Ideas in Psychology, 18*(2–3), 187-213. doi: http://dx.doi.org/10.1016/S0732-118X(00)00008-8

Dissociation of ions in aqueous solution. (2010).   Retrieved September 18, 2013, from http://www.youtube.com/watch?v=bgWOOe0KFFk

Driscoll, M. P. (2005). *Psychology of learning for instruction* (3rd ed.). Boston: Pearson Allyn and Bacon.

dry-ice-shipment.jpg. (n.d.).   Retrieved September 18, 2013, from http://www.maineoxy.com/images/dry-ice-shipment.jpg

Dry Ice. (2010).   Retrieved September 16, 2013, from http://www.youtube.com/watch?v=6JzQ08AGuhI

Elmesky, R. (2003). Crossfire on the streets and into the classroom: Meso/micro understandings of weak cultural boundaries, strategies of action and a sense of the game in an inner-city chemistry classroom. *Cybernetics & Human Knowing, 10*(2), 29-50.

Elmesky, R., & Seiler, G. (2007). Movement expressiveness, solidarity and the (re)shaping of African American students' scientific identities. *Cultural Studies of Science Education, 2*(1), 73-103. doi: 10.1007/s11422-007-9050-4

Emdin, C. (2009). Urban science classrooms and new possibilities: on intersubjectivity and grammar in the third space. *Cultural Studies of Science Education, 4*(1), 239-254.

Eslinger, E., White, B., Frederiksen, J., & Brobst, J. (2008). Supporting inquiry processes with an interactive learning environment: Inquiry Island. *Journal of Science Education & Technology, 17*(6), 610-617. doi: 10.1007/s10956-008-9130-6

Evans, M. J., & Moore, J. S. (2011). A collaborative, wiki-based organic chemistry project incorporating free chemistry software on the web. *Journal of Chemical Education, 88*(6), 764-768. doi: 10.1021/ed100517g

FACET Innovations. (2012). Diagnoser tools. Retrieved August 6, 2012 http://www.diagnoser.com/application/teacherloginpage

Faul, F., Erdfelder, E., & Lang, A.-G. B., Axel. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175-191.

Festinger, L. (1957). *A theory of cognitive dissonance*. Evanston, Ill.,: Row.

Gilligan, C. (1993). *In a different voice : psychological theory and women's development*. Cambridge, Mass.: Harvard University Press.

girls-walking.jpg. (n.d.).   Retrieved 2013, September 16, from http://mooiness.com/images/girls-walking.jpg

Gnadinger, C. M. (2001). *Peer scaffolding during joint productive activity in multi-age settings.* (Doctoral dissertation). ProQuest Dissertations & Theses database. (3027078)

Gonzalez, N., Moll, L. C., Tenery, M. F., Rivera, A., Rendon, P., Gonzales, R., & Amanti, C. (1995). Funds of knowledge for teaching in Latino households. *Urban Education, 29*(4), 443-470. doi: 10.1177/0042085995029004005

Hand, B., Yang, O. E.-M., & Bruxvoort, C. (2007). Using writing-to-learn science strategies to improve year 11 students' understandings of stoichiometry. *International Journal of Science & Mathematics Education, 5*(1), 125-143.

Hansen, S., Berente, N., & Lyytinen, K. (2009). Wikipedia, critical social theory, and the possibility of rational discourse. *Information Society, 25*(1), 38-59. doi: 10.1080/01972240802587562

Harlem Shake (original army edition). (2013).   Retrieved September 18, 2013, from http://www.youtube.com/watch?v=4hpEnLtqUDg

Harris, A. D., McGregor, J. C., Perencevich, E. N., Furuno, J. P., Zhu, J., Peterson, D. E., & Finkelstein, J. (2006). The use and interpretation of quasi-experimental studies in medical informatics. *J Am Med Inform Assoc, 13*(1), 16-23. doi: 10.1197/jamia.M1749

Haydel Debarger, A., Ayala, C., Minstrell, J., Kraus, P., & Stanford, T. (2009). *Facet-based progressions of student understanding in Chemistry*. Paper presented at the American Educational Research Association, San Diego. http://chemfacets.sri.com/downloads/ChemFacetsTR1.pdf

Heid, P. F. (2011). Writing chemistry jingles as an introductory activity in a high school chemistry class. *Journal of Chemical Education, 88*(10), 1394-1396. doi: 10.1021/ed1010147

Hilton, A., & Nichols, K. (2011). Representation classroom practices that contribute to students' conceptual and representational understanding of chemical bonding. *International Journal of Science Education, 33*(16), 2215-2246.

Holm, A., & Travalglini, C. (2005). *Chemistry 101 Laboratory Manual*. Champaign, IL: Stipes Publishing.

Image002.jpg. (n.d.). Retrieved September 18, 2013, from http://physicaplus.org.il/zope/home/1223030912/god_particle_en/Image002.jpg?display=

Jegede, O., Taplin, M., Fan, R. Y. K., Chan, M. S. C., & Yum, J. (1999). Differences between low and high achieving distance learners in locus of control and metacognition. *Distance Education, 20*(2), 255-273. doi: 10.1080/0158791990200206

Jeong, A. (2012). *The sequential analysis of indvidual versus collaborative writing processes in wikis*. Paper presented at the American Educational Research Association Annual Meeting, Vancouver, BC.

Johnson, D. W., & Johnson, R. T. (1999). Making cooperative learning work. *Theory Into Practice, 38*(2), 67-73. doi: 10.2307/1477225

Johnson, R. T., & Johnson, D. W. (1994). An overview of cooperative learning. In J. S. Thousand, R. A. Villa & A. Nevin (Eds.), *Creativity and collaborative learning : a practical guide to empowering students and teachers*. Baltimore: P.H. Brookes Pub. Co.

Kelly, R. M., Barrera, J. H., & Mohamed, S. C. (2009). An analysis of undergraduate General Chemistry students' misconceptions of the submicroscopic level of precipitation reactions. *Journal of Chemical Education, 87*(1), 113-118. doi: 10.1021/ed800011a

Kurt, M. (2007). Activating metacognition through online learning log (OLL). Retrieved March 8, 2013 http://www.eric.ed.gov/ERICWebPortal/detail?accno=ED500092

Kurtèn-Finnäs, B. (2012). "It was interesting when you had to think so much." Open investigations and Vee-heuristics within education in chemistry. Retrieved April 30, 2013, from https://www.journals.uio.no/index.php/nordina/article/view/353/387

Larusson, J. A. A., Richard. (2009). Wikis to support the "collaborative" part of collaborative learning. *Computer-Supported Collaborative Learning, 4*, 371-402.

Lattice Energies - Chemistry Tutorial. (2011). Retrieved September 18, 2013, from http://www.youtube.com/watch?v=EwnU8RalZOw

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Lazda-Cazers, R. (2010). A course wiki: challenges in facilitating and assessing student-generated learning content for the humanities classroom. *Journal of General Education, 59*(4), 193-222.

Lee, L. (2010). Exploring wiki-mediated collaborative writing: A case study in an elementary Spanish course. *CALICO, 27*(2), 260-276.

Lee, O. (2005). Science education With english language learners: Synthesis and research Agenda. *Review of Educational Research, 75*(4), 491-530.

Lee, O., & Luykx, A. (2005). Dilemmas in scaling up innovations in elementary science instruction with nonmainstream students. *American Educational Research Journal, 42*(3), 411-438.

Li, X., Zhang, L., Mao, R., Zhao, Q., & Stanton, B. (2011). Effect of social cognitive theory-based HIV education prevention program among high school students in Nanjing, China. *Health Education Research, 26*(3), 419-431. doi: 10.1093/her/cyr001

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry*. Beverly Hills, CA: Sage.

Liquid nitrogen boiling in a beaker. (2008). Retrieved September 18, 2013, from http://www.youtube.com/watch?v=_9MI5BvOmLk

Lund, A. (2008). Wikis: a collective approach to language production. *ReCALL, 20*(1), 35-54.

MacGregor, J. T. (1992). Collaborative learning: Reframing the classroom. In A. S. Goodsell, M. R. Maher, V. Tinto, B. L. Smith & J. MacGregor (Eds.), *Cooperative learning: A sourcebook for higher education* (pp. 37-40). University Park, PA: National Center on Postsecondary Teaching, Learning, and Assessment.

MacGregor, S. K., & Lou, Y. (2004). Web-based learning: How task scaffolding and web site design support knowledge acquisition. *Journal of Research on Technology in Education, 37*(2), 161-175.

Mahn, H. (2003). Periods in child development. In A. Kozulin, B. Gindis, V. S. Ageyev & S. Miller (Eds.), *Vygotsky's educational theory in cultural context* (pp. 119-137). UK ; New York: Cambridge University Press.

Manlove, S., Lazonder, A., & Jong, T. (2007). Software scaffolds to promote regulation during scientific inquiry learning. *Metacognition and Learning, 2*(2-3), 141-155. doi: 10.1007/s11409-007-9012-y

Marusic, M., & Slisko, J. (2012). Influence of three different methods of teaching physics on the gain in students' development of reasoning. *International Journal of Science Education, 34*(2), 301-326. doi: 10.1080/09500693.2011.582522

Matthew, K. I., Felvegi, E., & Callaway, R. A. (2009). Wiki as a collaborative learning tool in a Language Arts methods class. *Journal of Research on Technology in Education, 42*(1), 51-72.

Minstrell, J. (2012). [personal communication].

Mixtures and Compounds. (n.d.).   Retrieved Sept 16, 2013, from http://www.youtube.com/watch?feature=player_embedded&v=cL6I1O1YHH0

Mortimer, E. F., & Wertsch, J. V. (2003). The architecture and dynamics of intersubjectivity in science classrooms. *Mind, Culture, and Activity, 10*(3), 230-244.

Moskaliuk, J., Kimmerle, J., & Cress, U. (2009). Wiki-supported learning and knowledge building: effects of incongruity between knowledge and information. *Journal of Computer Assisted Learning, 25*(6), 549-561.

Mulford, D. R., & Robinson, W. R. (2002). An inventory for alternate conceptions among first-semester General Chemistry students. *Journal of Chemical Education, 79*(6), 739. doi: 10.1021/ed079p739

National Center for Education Statistics. (2012). The nation's report card Retrieved July 29, 2012, from http://nationsreportcard.gov/science_2009/g12_nat.asp?tab_id=tab2&subtab_id=Tab_3#tabsContainer

Niaz, M. (1995). Cognitive conflict as a teaching strategy in solving chemistry problems - a dialectic-constructivist perspective. *Journal of Research in Science Teaching, 32*(9), 959-970. doi: 10.1002/tea.3660320907

Novick, S., & Nussbaum, J. (1981). Pupils' understanding of the particulate nature of matter: A cross-age study. *Science Education, 65*(2), 187-196. doi: 10.1002/sce.3730650209

Nunn, L. M. (2011). Classrooms as racialized spaces. *Urban Education, 46*(6), 1226-1255. doi: 10.1177/0042085911413146

O'Neil, M. (2010). Shirky and Sanger, or the costs of crowdsourcing. *Journal of Science Communication, 9*(1).

Orosco, M. J. (2010). A sociocultural examination of response to intervention with Latino English language learners. *Theory Into Practice, 49*(4), 265-272.

Othman, J., Treagust, D. F., & Chandrasegaran, A. L. (2008). An investigation into the relationship between students' conceptions of the particulate nature of matter and their understanding of chemical bonding. *International Journal of Science Education, 30*(11), 1531-1550. doi: 10.1080/09500690701459897

Özmen, H., Demircioğlu, H., & Demircioğlu, G. (2009). The effects of conceptual change texts accompanied with animations on overcoming 11th grade students' alternative conceptions of chemical bonding. *Computers & Education, 52*(3), 681-695. doi: 10.1016/j.compedu.2008.11.017

Palincsar, A. S. (1998). Keeping the metaphor of scaffolding fresh—-a response to C. Addison Stone's "The metaphor of scaffolding: Its utility for the field of learning disabilities". *Journal of Learning Disabilities, 31*(4), 370-373. doi: 10.1177/002221949803100406

Pallant, J. (2010). *SPSS survival manual : a step by step guide to data analysis using the SPSS program* (4th ed.). Maidenhead, Berkshire. U.K. ; New York, NY: Open University Press.

Patten, M. (2012). *Understanding Research Methods*. Glendale, CA: Pyrczak Publishing.

Peterson, R. A. (1994). A meta-analysis of Cronbach's coefficient alpha. *Journal of Consumer Research, 21*(2), 381-391. doi: 10.2307/2489828

Piaget, J. (2008). Development and learning. In M. Gauvain & M. Cole (Eds.), *Readings on the development of children* (5th ed., pp. 33-41). New York, NY: Worth Publishers.

Plankis, B. J. (2009). *Examining the effects of technology-infused issue investigations on high school students' environmental and ocean literacies.* (Doctoral Dissertation). ProQuest Dissertations & Theses database. (3358083)

Prezi. (2013). Retrieved March 12, 2013, from http://prezi.com/

Puntambekar, S., & Hübscher, R. (2005). Tools for scaffolding students in a complex learning environment: What have we gained and what have we missed? *Educational Psychologist, 40*(1), 1-12. doi: 10.1207/s15326985ep4001_1

Puntambekar, S., & Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science from design. *Journal of Research in Science Teaching, 42*(2), 185-217. doi: 10.1002/tea.20048

Puzziferro, M. (2008). Online technologies self-efficacy and self-regulated learning as predictors of final grade and satisfaction in college-level online courses. *American Journal of Distance Education, 22*(2), 72-89.

Really bad dancing. (2006). Retrieved September 18, 2013, from http://www.youtube.com/watch?v=qwVa06LSlxk

Reich, J., Murnane, R., & Willett, J. (2012a). *Are great classroom wikis born or made? Using Continuous-Time Data to Model Longitudinal Development in Online Learning Environments*. Paper presented at the American Educational Research Association Annual Meeting, Vancouver, BC.

Reich, J., Murnane, R., & Willett, J. (2012b). *Just posting in the same place? A taxonomy of collaborative behaviors in U.S. K-12 wikis.* Paper presented at the American Educational Research Association Annual Meeting, Vancouver, BC.

Reich, J., Murnane, R., & Willett, J. (2012c). The state of wiki usage in U.S. K-12 schools. *Educational Researcher, 41*(1), 7-15. doi: 10.3102/0013189x11427083

Reisslein, J., Reisslein, M., & Seeling, P. (2006). Comparing static fading with adaptive fading to independent problem solving: The impact on the achievement and attitudes of high school students searning electrical circuit analysis. *Journal of Engineering Education, 95*(3), 217-226.

Richards, E. (2012). Laptops replace lectures in some area schools: Technology adds new flexibility to lessons Retrieved June 7, 2013, from http://www.jsonline.com/news/education/laptops-replace-lectures-in-some-area-schools-ru54mlr-149392325.html

Rogoff, B. (1990). *Apprenticeship in thinking : cognitive development in social context.* New York: Oxford University Press.

Rose, M. A. (2004). Comparing productive online dialogue in two group styles: cooperative and collaborative. *The American Journal of Distance Education, 18*(2), 73-88. doi: http://dx.doi.org/10.1207/s15389286ajde1802_2

Rosenshine, B., Meister, C., & Chapman, S. (1996). Teaching students to generate questions: A review of the intervention studies. *Review of Educational Research, 66*(2), 181.

Rumberger, R. W., & Tran, L. (2009). Investigating state, district, and school variability in the English learner achievement gap: UC Santa Barbara.

Scerri, E. R. (2007). *The periodic table : its story and its significance.* Oxford ; New York: Oxford University Press.

Schmidt, H.-J., Baumgärtner, T., & Eybe, H. (2003). Changing ideas about the periodic table of elements and students' alternative concepts of isotopes and allotropes. *Journal of Research in Science Teaching, 40*(3), 257-277. doi: 10.1002/tea.10076

Schweizer, H., Hayslett, C., & Lowe, R. (2003). Rebooting the promise of technology in the classroom. *Journal of Educational Computing Research, 29*(2), 277-284.

Seiler, G., & Elmesky, R. (2007). The role of communal practices in the generation of capital and emotional energy among urban African American students in science classrooms. *Teachers College Record, 109*(2), 391-419.

Shulman, L. S., & Wilson, S. M. (2004). *The wisdom of practice : essays on teaching, learning, and learning to teach* (1st ed.). San Francisco: Jossey-Bass.

SRI International. (2012). Chemistry facets: formative assessment to improve student understanding in chemistry Retrieved August 6, 2012, 2012, from http://ctl.sri.com/projects/displayProject.jsp?Nick=chemfacets

States of Matter. (n.d.).   Retrieved Sept 16, 2013, from http://www.media.pearson.com.au/schools/cw/au_sch_whalley_sf1_1/int/matter.html

Stone, C. A. (1998). The metaphor of scaffolding: its utility for the field of learning disabilities. *Journal of Learning Disabilities, 31*(4), 344-364.

Stout, R. P. (1997). Good writing assignments = good thinking: A proven WID philosophy Retrieved July 11, 2012, from http://wac.colostate.edu/llad/v2n2/stout.pdf

Stout, R. P. (2010). "Hello, I'm Carbon.": Writing about elements and compounds. *Journal of Chemical Education, 87*(11), 1163-1165. doi: 10.1021/ed1000069

Structure of diamond and graphite. (2010).   Retrieved September 18, 2013, from http://www.youtube.com/watch?v=fuinLNKkknI

Sublimation. (n.d.).   Retrieved Sept 16, 2013, from http://www.media.pearson.com.au/schools/cw/au_sch_lewis_cw1/int/sublimation/f11/1108.html

Tabak, I. (2004). Synergy: A complement to emerging patterns of distributed scaffolding. *The Journal of the Learning Sciences, 13*(3), 305-335.

Tan, K.-C. D., & Treagust, D. F. (1999). Evaluating students' understanding of chemical bonding. *School Science Review, 81*(294), 75-83.

Tangient LLC. (2013).   Retrieved May 5, 2013, from http://www.wikispaces.com/

Thomas, G. P., & McRobbie, C. J. (2001). Using a metaphor for learning to improve students' metacognition in the chemistry classroom. *Journal of Research in Science Teaching, 38*(2), 222-259.

Tro, N. J. (2003). *Introductory chemistry*. Upper Saddle River, N.J.: Prentice Hall.

untitled-1. (n.d.).   Retrieved September 17, 2013, from http://4.bp.blogspot.com/-E1NtY4EOQSM/Td_D-A2W4oI/AAAAAAAAAms/61EF27hSPKM/s1600/n38001724_30901719_69061.jpg

untitled-2. (n.d.).   Retrieved September 17, 2013, from http://4.bp.blogspot.com/-w4B05nEtLTI/TcfWISzq5OI/AAAAAAAACr8/7WywnO0B85Y/s1600/DSC_0053.JPG

Uzuntiryaki, E. (2003). *Effectiveness of constructivist approach on students' understanding of chemical bonding concepts.* (Doctoral dissertation), The Middle East Technical University. Retrieved from http://etd.lib.metu.edu.tr/upload/3/692046/index.pdf

Vacha-Haase, T., Ness, C., Nilsson, J., & Reetz, D. (1999). Practices regarding reporting of reliability coefficients: A review of three journals. *The Journal of Experimental Education, 67*(4), 335-341. doi: 10.2307/20152606

Valanides, N., & Angeli, C. (2008). Distributed cognition in a sixth-grade classroom: An attempt to overcome alternative conceptions about light and color. *Journal of Research on Technology in Education, 40*(3), 309-336.

Vallance, M., Towndrow, P., & Wiz, C. (2010). Conditions for successful online document collaboration. *TechTrends, 54*(1), 20-24.

van der Veer, R. (1986). Vygotsky's developmental pyschology. *Psychological Reports, 59*(2), 527-536. doi: 10.2466/pr0.1986.59.2.527

van der Veer, R. (1994). The concept of development and the development of concepts. Education and development in Vygotsky's thinking. *European Journal of Psychology of Education, 9*(4), 293-300. doi: 10.1007/bf03172902

Vygotsky, L. (2008). Interaction between learning and development. In M. Gauvain & M. Cole (Eds.), *Readings on the development of children* (5th ed., pp. 42-49). New York, NY: Worth Publishers.

Vygotsky, L. S., Rieber, R. W., & Carton, A. S. (1987). *The collected works of L.S. Vygotsky* (Vol. 1: Problems of General Psychology, including the volume Thinking and Speech). New York: Plenum Press.

Vygotsky, L. S., van der Veer, R., & Valsiner, J. (1994). *The Vygotsky reader*. Oxford, UK ; Cambridge, Mass., USA: Blackwell.

Wang, F., & Hannafin, M. J. (2008). Integrating WebQuests in preservice teacher education. *Educational Media International, 45*(1), 59-73. doi: 10.1080/09523980701847214

Wang, J.-R., & Lin, S.-W. (2009). Evaluating elementary and secondary school science learning environments in Taiwan. *International Journal of Science Education, 31*(7), 853-872.

Wertsch, J. V. (1984). The zone of proximal development: Some conceptual issues. *New Directions for Child and Adolescent Development, 1984*(23), 7-18. doi: 10.1002/cd.23219842303

Whiston, S. C. (2009). *Principles and applications of assessment in counseling* (3rd ed.). Australia ; Belmont, CA: Brooks/Cole, Cengage Learning.

White, C. J. (1999). The metacognitive knowledge of distance learners. *Open Learning, 14*(3), 37.

Willett, J. B. (1988). Questions and answers in the measurement of change. *Review of Research in Education, 15*, 345-422. doi: 10.2307/1167368

Wisconsin Information Network for Successful Schools. (n.d.).   Retrieved April 8, 2011, from http://dpi.wi.gov/sig/index.html

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17*(2), 89-100.

Wu, H.-L. (2010). Scaffolding in technology-enhanced science education (Doctoral dissertation). ProQuest Dissertations & Theses. (3416373).

Zoller, U., Lubezky, A., Nakhleh, M. B., Tessier, B., & Dori, Y. J. (1995). Success on algorithmic and LOCS vs. conceptual chemistry exam questions. *Journal of Chemical Education, 72*(11), 987. doi: 10.1021/ed072p987

Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2007). *World of chemistry*. Evanston, Ill.: McDougal Littell.

Appendix A

Elements and Atomic Structure Pre/Posttest (Trial Run)

Name _____   **Period** _____

Circle the letter of the choice that best answers the question.

1) A particular atom has 11 electrons, 11 protons, and 12 neutrons.

   Which of these other atoms or ions listed in the table can also be considered to be the same element?

Type of Atom	Number of Electrons	Number of Protons	Number of Neutrons
I	10	12	11
II	11	11	11
III	10	11	12
IV	11	12	11

    a. II & IV
    b. II & III
    c. I & III
    d. III only
    e. None of them

(FACET Innovations, 2012; I added choice "d" as another distractor)

2) When scientists explore other planets in our solar system, they want to gather material to learn more about what kinds of elements exist on the planets.

   What do you think they are finding?

    a. The same kinds of elements that we have on Earth.
    b. New kinds of elements that have never been discovered before.
    c. Both the same kinds of elements that we have on Earth AND new kinds of elements.
    d. They are not finding any elements.

(FACET Innovations, 2012; I added choice "d" as another distractor)

3) Which one of the following statements about atomic structure is *false*?

   a. Almost all of the mass of the atom is concentrated in the nucleus.
   b. The electrons occupy a very large volume compared to the nucleus.
   c. The protons and neutrons in the nucleus are very tightly packed.
   d. All of these statements (a-c) are true.

   (Question adapted from one of my old exams; original source unknown)

4) If scientists could change tin into silver, what part of the tin atoms would they have to change to make silver atoms?

   a. Scientists would have to change the number of protons in tin atoms.
   b. Scientists would have to change the number of electrons in tin atoms.
   c. Scientists would have to change the number of neutrons in tin atoms.
   d. Scientists would have to change the total number of nuclear particles (protons and neutrons) in tin atoms.
   e. Scientists would have to change the number of electrons, protons, and neutrons.

   (FACET Innovations, 2012)

5) Your brother wonders, "Can you make salt?" You remember that your teacher told your class that one kind of salt is sodium chloride or NaCl.

   Which statement below would best answer your brother's question?

   a. No. Salt is an element composed of salt atoms because it is a substance found in nature.
   b. Yes. All atoms can be made, so even if salt is an element, it can be made.
   c. Maybe. If salt is an element, then no, you cannot MAKE an element easily. If salt is made from other elements, then yes.
   d. None of the above

   (FACET Innovations, 2012)

6) If an element has an atomic number of 6, which statement must be true of *all* the atoms of that element?

   a. The mass of the atom is 12 amu
   b. The nucleus of the atom contains 6 protons
   c. The nucleus of the atom contains 6 protons and 6 neutrons
   d. The nucleus of the atom contains 6 protons and 6 electrons
   e. None must be true of all atoms

   (loosely based on Schmidt, Baumgärtner, & Eybe, 2003; I added choices a, d, and e as distractors)

7) The atomic number of the element magnesium is 12, and its atomic mass is 24.3 amu. The mass numbers of its three natural isotopes are 24, 25, and 26. Which of the following statements is *false*?

    a. One of the isotopes has 12 neutrons
    b. The three isotopes have the same nuclear charge
    c. The mass number of the most abundant isotope is 26
    d. Some atoms of magnesium have more neutrons than protons
    e. None are false

    (adapted from Zoller, Lubezky, Nakhleh, Tessier, & Dori, 1995)

8) An atom of $^{18}_{8}O$ has how many neutrons?

    a. 8
    b. 10
    c. 12
    d. 14
    e. 18

    (Question adapted from one of my old exams; original source unknown)

9) About how many elements can be found in nature?

    a. Only a limited number can be found anywhere (around 100 or so).
    b. There are as many elements as there are different types of substances.
    c. There are a limited number of elements on Earth, plus a lot more found on other planets and stars.
    d. It is impossible to know since new elements are being found all the time.

    (FACET Innovations, 2012; I added choice "d" as another distractor)

10) A science teacher shows students two objects that are made of gold. One is a chunk of gold (a gold nugget) recently mined, while the other is a piece of gold made to be very thin, which is called gold leaf.

How would a picture of one gold atom from the nugget compare to a picture of one gold atom from the gold leaf?

    a. An atom in the nugget is rough, while an atom from the leaf would be smooth.
    b. An atom in the nugget is natural, while an atom from the leaf would be flattened.
    c. Both statements above are correct.
    d. The atoms in the gold nugget and the gold foil would be the same.

    (FACET Innovations, 2012)

**Appendix B**

Bonding Pre/Posttest (Activity #1)

Name _____   **Period** _____

Part A: Multiple Choice. Circle the letter of the choice that best answers the question.

1) What type of bond forms between carbon and oxygen?

   a. nonpolar covalent
   b. polar covalent
   c. ionic
   d. metallic

2) Imagine there is a generic compound XY. What, if any, type of bond will form
   between X and Y if elements X and Y have a small difference in electronegativity?

   a. Their atoms repel each other; no bond will form.
   b. The bond will be primarily ionic.
   c. The bond will be primarily covalent.
   d. Not enough information provided to answer the question.

3) Which of the following statements are true?

   a. In the O-H bond, oxygen has the partial positive charge
   b. In the Si-Cl bond, silicon has the partial positive charge
   c. A bond between two nonmetals is always nonpolar covalent
   d. A double covalent bond involves the sharing of two electrons
   e. b, c, and d are true

4) A nonpolar bond will form between two _____ atoms of _____
   electronegativity.

   a. different, opposite
   b. identical, different
   c. different, different
   d. similar, different
   e. identical, equal

5) Which of the following bonds would be most polar:

   a. O-F
   b. N-F
   c. C-F
   d. B-F
   e. F-F

6) Which of the following statements is true about chemical bonds?

   a. A bond is a physical entity that attaches one atom to another.
   b. A bond is what happens when two atoms want to join each other.
   c. A bond is what happens when atoms share or transfer electrons and are joined together in a lower energy state than when they are apart.
   d. A bond is what happens when all of the electrons of one atom are shared with all of the electrons of another atom

Part B: Two-Tiered Questions. Each of these questions has two parts. *For the first part*, **circle the <u>number</u>** that best answers the question. *For the second part*, **circle the <u>letter</u>** that gives the reason for your answer to the first part.

7) Which of the following best represents the position of the shared electron pair in the HF molecule?

   (1) H $\mathbf{:}$ F   (2) H $\mathbf{:}$ F

   The reason for my answer is:

   a. Non-bonding electrons influence the position of the bonding or shared electron pair
   b. As hydrogen and fluorine form a covalent bond the electron pair must be centrally located
   c. Fluorine has a stronger attraction for the shared electron pair
   d. Fluorine is the larger of the two atoms and hence exerts greater control over the shared electron pair

8) In hydrogen chloride, HCl, the bond between hydrogen and chloride is

   (1) covalent   (2) ionic

   The reason for my answer is:

   a. Electrons are shared between atoms.
   b. Electrons are transferred.
   c. It contains different atoms.
   d. It contains a Cl atom.

9) The bonds in H_2O are

(1) polar   (2) nonpolar   (3) ionic

The reason for my answer is:

a. Shared electrons are attracted equally.
b. Shared electrons concentrate around one atom.
c. Nonbonding electrons affect the position of shared electrons.
d. Valence electrons in each atom determine polarity.
e. Electrons are transferred.

10) Calcium chloride, $CaCl_2$, is a/an

(1) covalent compound   (2) ionic compound   (3) metallic substance

The reason for my answer is:

a. Electrons are shared between atoms.
b. Electrons are transferred.
c. Ability of Ca to attract electrons is similar to that of Cl.
d. Ca has a much higher electronegativity than Cl
e. Both a and d

Appendix C

Physical Changes Pre/Posttest (Activity #2)

Name _____   **Period** _____

Part A: Multiple Choice. Circle the letter of the choice that best answers the question.

1) Ali mixed 50 ml of alcohol with 50 ml of water. No reaction occurred and neither of the liquids evaporated. She was surprised to notice that the final volume of the alcohol-water solution was less than 100 ml.

    Suppose that Ali weighs the alcohol and the water before mixing and then weighs the alcohol-water solution after mixing.

    How does the weight of the liquids compare before and after they are mixed?

    a. The alcohol-water solution after mixing weighs less.
    b. The alcohol-water solution after mixing weighs more.
    c. They weigh the same before and after mixing.
    d. Not enough information provided to answer the question.

2) Which of the following statements best matches your reasoning on the previous question?

    a. There are fewer atoms in the mixed solution compared to the number of atoms in the alcohol and water before mixing.
    b. There are more atoms in this mixed solution compared to the number of atoms in the alcohol and water before mixing, but the atoms are just more tightly packed in the mixed solution.
    c. There is the same number of atoms before and after mixing the alcohol and water, but the atoms are just more tightly packed in the mixed solution.
    d. Not enough information was provided to answer the question.

3) Assume a beaker of pure water has been boiling for 30 minutes. What is in the bubbles in the boiling water?

    a. air
    b. oxygen gas and hydrogen gas
    c. oxygen
    d. water vapor
    e. heat

4) A 1.0-gram sample of solid iodine is placed in a tube and the tube is sealed after all of the air is removed. The tube and the solid iodine together weigh 27.0 grams.

iodine solid
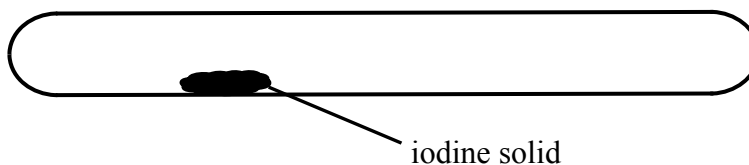
The tube is then heated until all of the iodine evaporates and the tube is filled with iodine gas. The weight after heating is:

a. less than 26.0 grams.
b. 26.0 grams.
c. 27.0 grams.
d. 28.0 grams.
e. more than 28.0 grams.

5) What is the reason for your answer to the previous question?

a. a gas weighs less than a solid
b. mass is conserved
c. iodine gas is less dense than solid iodine
d. gases rise
e. iodine gas is lighter than air

6) Students were talking about what happens to nitrogen atoms when liquid nitrogen changes into nitrogen gas.

Rosa said: *"There are different kinds of nitrogen atoms. Liquid nitrogen atoms are present when the nitrogen is a liquid, and gaseous nitrogen atoms are present when the Nitrogen is a gas."*

Caesar said: *"When nitrogen changes from a liquid to a gas, the nitrogen atoms change from visible to invisible."*

Lena said: *"The atoms stay the same when nitrogen changes from a liquid to a gas. The atoms in the gas are just much farther apart."*

Who do you agree with?

a. Rosa
b. Caesar
c. Lena
d. Rosa and Caesar

7) Select from the following pictures a sequence showing increasing temperature.

A

B

C

D

E

F

G

H
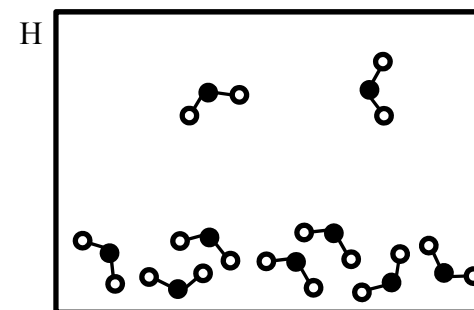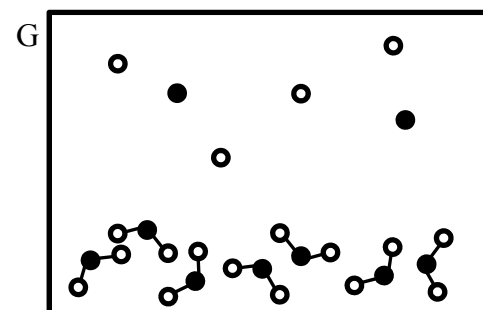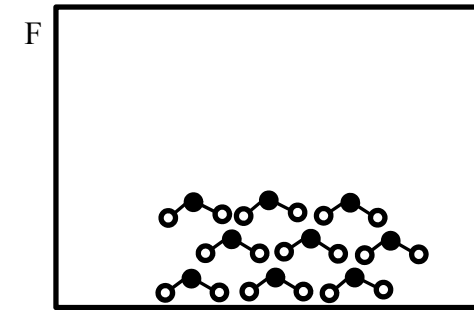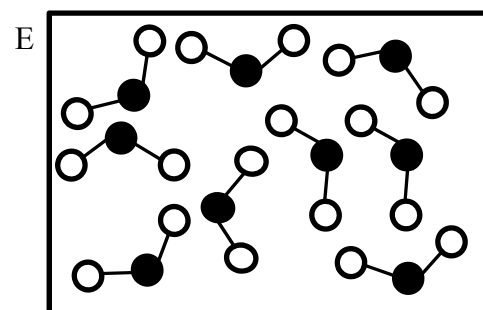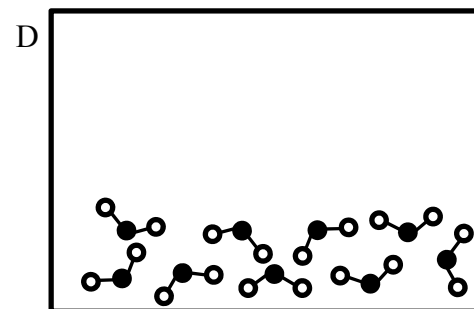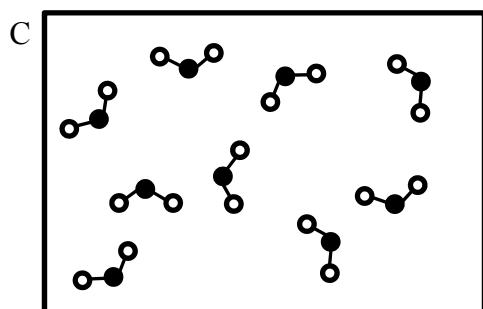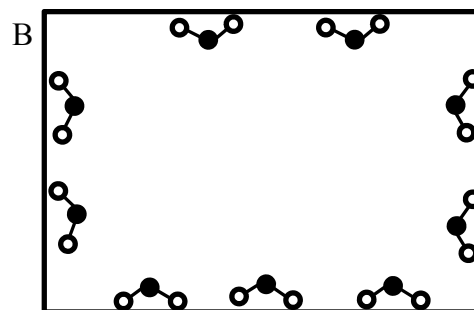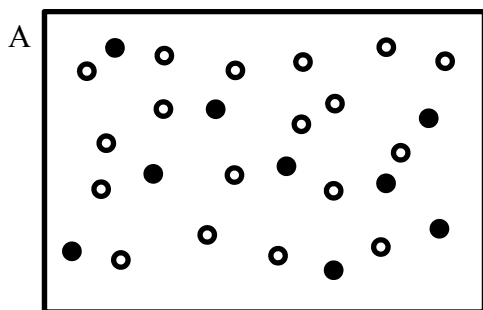
a. EDHC
b. FDHC
c. FDGA
d. FDHCB

e. EFDHCA
f. FDHCBA
g. FDHCGBA
h. FEDHCGA

Part B: Two-Tiered Question. This question has two parts. For the first part, circle the number that best answers the question. For the second part, circle the letter that gives the reason for your answer to the first part.

8) The circle on the left shows a magnified view of a very small portion of liquid water in a sealed container. (Key: oxygen ◯, hydrogen ●)
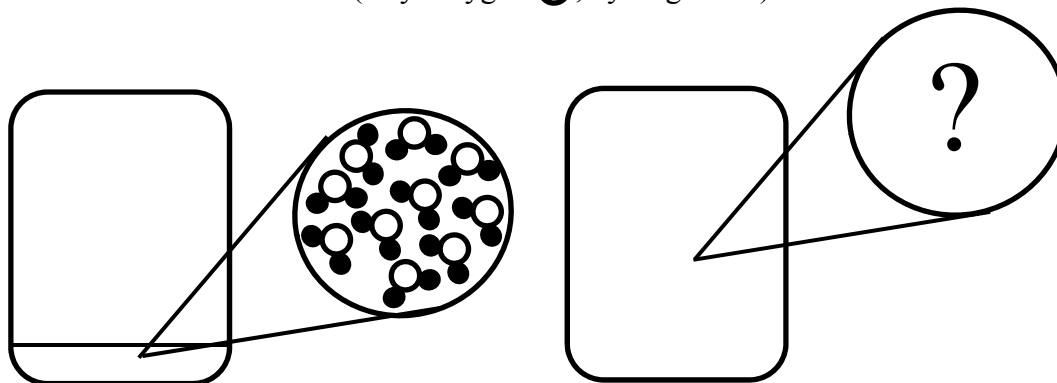
What would the magnified view look like after all the water has evaporated?

(1)   (2)   (3)   (4)   (5)
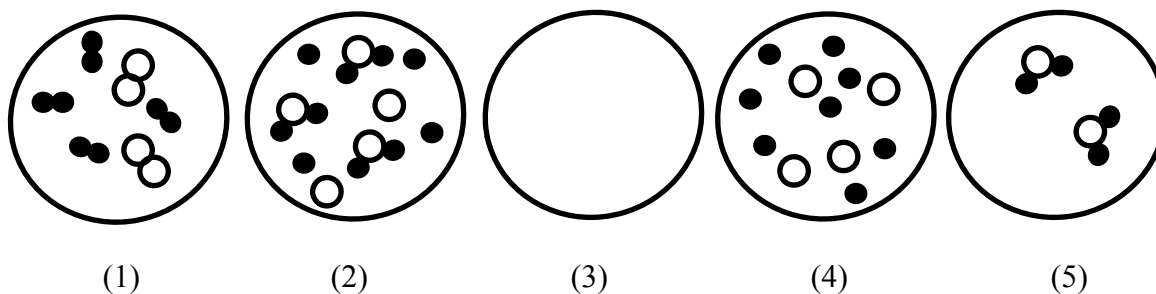
The reason for my answer is:

a. Water molecules have decomposed into oxygen atoms and hydrogen atoms.
b. Water molecules have escaped into the air.
c. Water molecules have decomposed into oxygen gas and hydrogen gas.
d. Water molecules have broken free of the attractions between each other and spread further apart.
e. A mixture of water molecules, oxygen atoms and hydrogen atoms is produced.

Part C: Matching.

9) The diagrams lettered A – D represent four different gases. The atoms of the
elements involved are given the symbols ⭕ and ⚫.

A   B   C   D
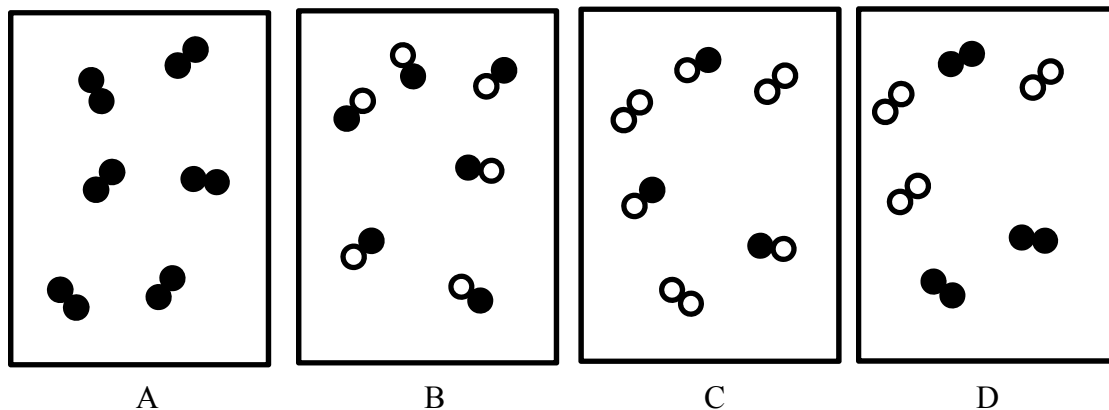
Identify which gas is described by the following (if you think more than one gas is
appropriate, you can write two or more letters on each line).

a mixture of the two elements _____

a compound _____

one element alone _____

Appendix D

Chemical Changes Pre/Posttest (Activity #3)

Name _____   **Period** _____

Part A: Multiple Choice. Circle the letter of the choice that best answers the question.

1) Aqueous solutions of two salts, sodium sulfate (Na_2SO_4(aq)) and barium chloride ($BaCl_2$(aq)), are placed in separate measuring cylinders on a top pan balance. The total mass is recorded as 140 g.

sodium sulfate solution

barium chloride solution

140.00 g
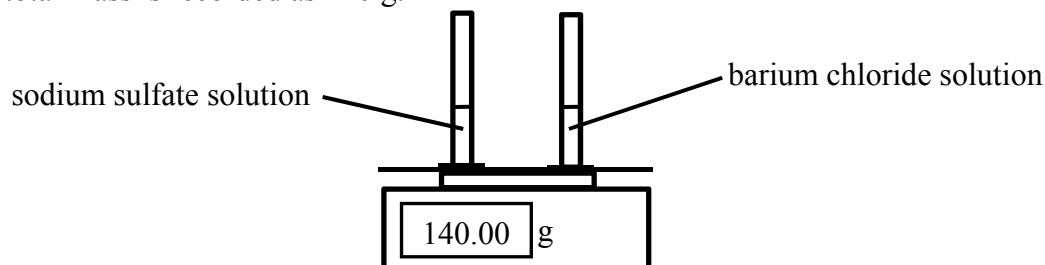
The sodium sulfate solution is then poured into the barium chloride solution. Both measuring cylinders stay on the balance. A precipitation reaction takes place.

precipitate

g
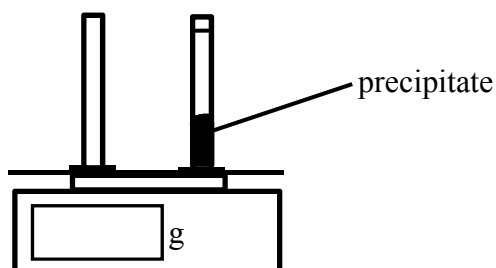
What will be the mass reading after the reaction takes place?

a. less than 140 g
b. 140 g exactly
c. more than 140 g
d. not enough information provided to answer the question

2) Which of the following is **true** regarding precipitation reactions?

    a. Sodium salts usually do not form precipitates
    b. Both pairs of reactant ions change partners
    c. Precipitates form because they are soluble in water
    d. "Aqueous", (aq), means a substance has changed into its liquid state
    e. Both a and b are true

3) A piece of paper burns in a closed flask. As it burns, which of the following statements is true?

    a. The number and type of atoms increase.
    b. The number and type of atoms decrease.
    c. The number and type of atoms remain the same.
    d. The number of atoms remains the same but the types of atoms change.
    e. The total mass decreases.
    f. Both b and e.

4) A piece of phosphorus and some water were placed in a flask. The flask was sealed with a rubber stopper. The mass of the flask and contents was 400 g. The sun's rays were focused on the flask. After the water evaporated, the phosphorus caught fire and a white smoke was produced. The flask was then cooled, the water condensed, and the white smoke slowly dissolved in the water. The mass of the flask was then measured again.
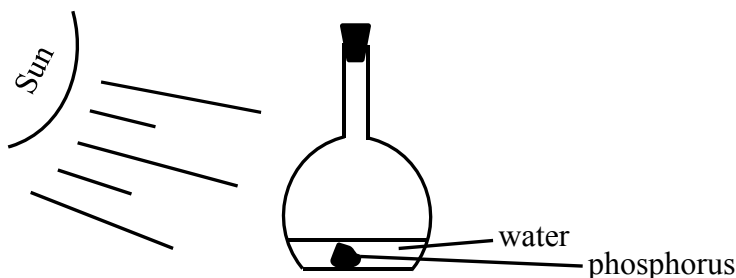
What would you expect the mass to be now?

    a. more than 400 g
    b. exactly 400 g
    c. less than 400 g
    d. not enough information provided to answer the question

For questions 5 and 6, consider the following precipitation reaction:

$KCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + KNO_3(aq)$
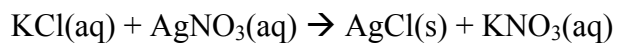
And that the ions can be represented as follows:

K^+	○
Cl^-	⊘
Ag^+	⊕
NO_3^-	✳

5) Which submicroscopic diagram best represents the KCl(aq) *prior to mixing* it with the AgNO₃(aq)?

a)

b)

c)

d)
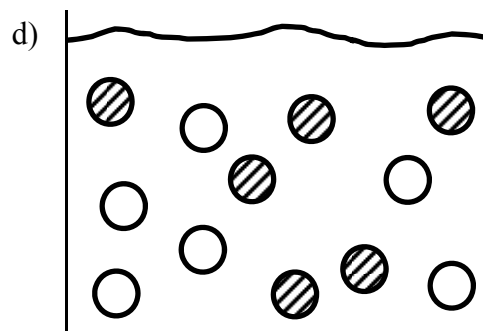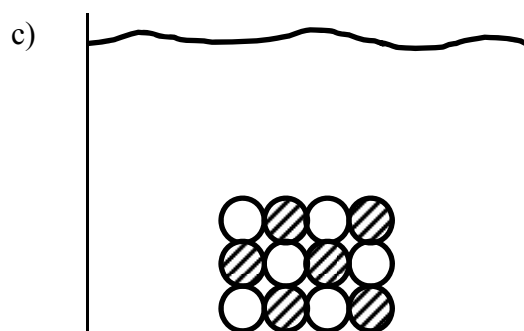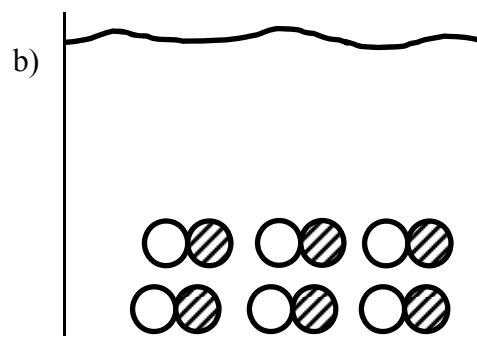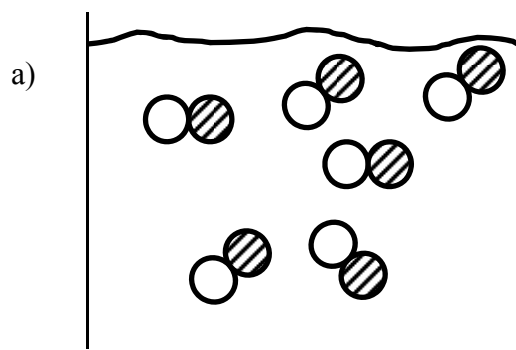
6) Which submicroscopic diagram best represents the *products* side of the chemical equation KCl(aq) + AgNO₃(aq) → *AgCl(s) + KNO₃(aq)*?

Reminder of which design represents which ion:

K⁺	⚪
Cl⁻	◍
Ag⁺	⊕
NO₃⁻	❈

a)

b)

c)

d)
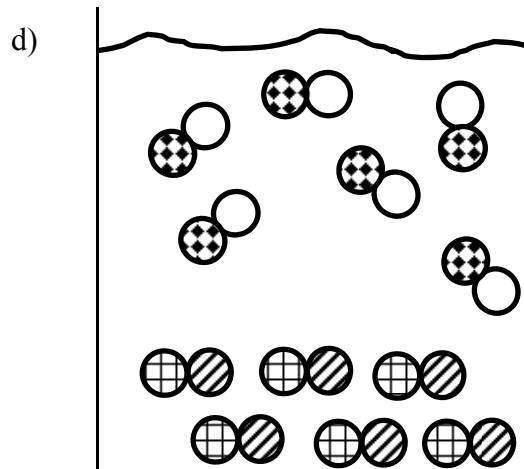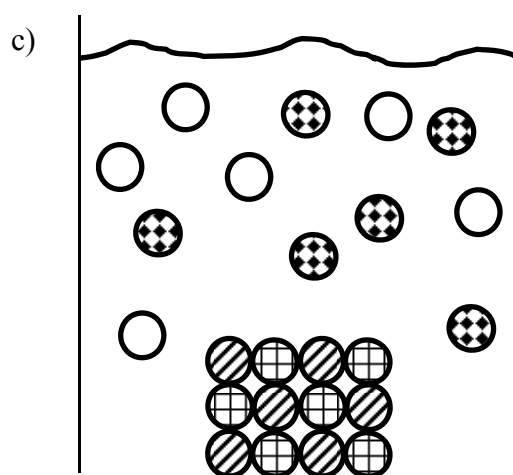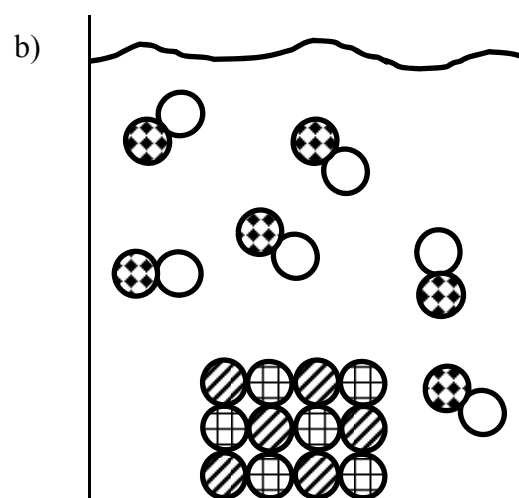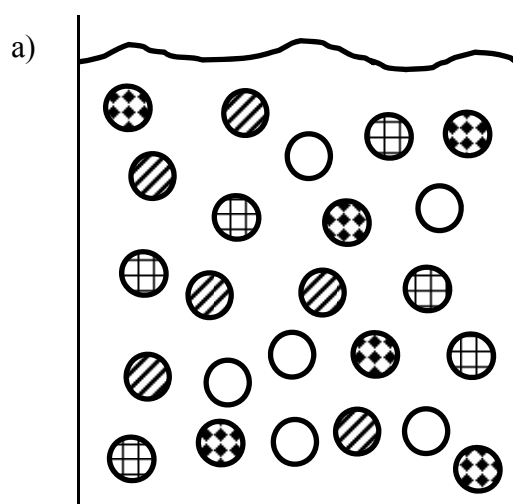
Part B: Varied Questions.

7) Consider the following precipitation reaction:

$K_2S(aq) + Pb(NO_3)_2(aq) \rightarrow PbS(s) + 2KNO_3(aq)$
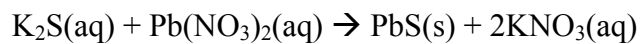
Which of the following statements is correct? (circle the best answer)

a. KNO_3 is the precipitate
b. PbS is soluble in water
c. Pb^{2+} and S^{2-} are spectator ions
d. K^+ and NO_3^- are spectator ions
e. K^+ is the only spectator ion

8) Explain your reason for the previous question.

9) Write the complete ionic equation and net ionic equation for the following reaction:

$BaI_2(aq) + 2AgNO_3(aq) \rightarrow 2AgI(s) + Ba(NO_3)_2(aq)$
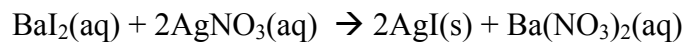
Appendix E

Partial Credit Awarded for Question 8 on Chemical Changes Pre/Posttest

Full credit

K^+ and NO^{3-} are the ions that are independent before and after the reaction OR not changing OR not doing anything in the reaction OR they don't react (acceptable if they didn't include the charges for potassium or nitrate because they were in the question anyway).

OR

They suggest that K^+ and NO_3^- are the spectator ions because they are aqueous and they state that the other ions are in the reaction (implying the potassium and nitrate are not part of the reaction).

0.70 pts

If they give an answer similar to the full credit BUT they refer to the potassium and nitrate as not doing anything in the equation without referring to the fact that an actual reaction took place (i.e. as if it was all about the equation as opposed to what the equation represents).

OR

If they just make a reference to the fact that they are spectator ions because they get crossed out in the equation.

OR

If they state KNO_3 is "just there doing nothing in the solution" or "not participating in the reaction" (not full credit because they didn't separate the two ions to demonstrate they were distinct and independent).

OR

If they put an answer similar to the full credit above, but just said they don't form precipitate (that doesn't make clear that they know it doesn't react at all).

OR

If they chose letter "e" for the previous question, and said that that ion did not participate in the reaction (not given full credit because the student showed no indication of realizing that the nitrate would also be a spectator ion).

OR

If they say that K^+ and NO_3^- are the spectator ions because they are the only ions in the reactants and products (this was not considered thorough enough to get full credit; it's sort of implied that potassium and nitrate are the only independent ions, but it's not clear they understand that; after all, the other two ions are also there before and after, the difference being that the other two ions are part of the solid after the reaction).

0.25 pts

For an answer that had some correct statement, even if one other aspect of the answer was incorrect. However, if more incorrect than correct statements were made, then no credit was awarded. An example of something that would receive 0.25 points is "KNO_3 is a precipitate because it is aqueous and it is soluble in water" (this is for someone who selected choice "a" in the previous question). In this case, KNO3, of course, is not the precipitate, but the student did correctly represent that something that is aqueous is soluble. As another example (also for someone who chose choice "a" in the previous question), "Because its an aqueous solution. It can dissolve easily".

0 pts

Answers that were blank or otherwise completely incorrect received no credit. Some responses such as "K is not on the solubility rules, meaning it's a spectator", which potentially represents the student learned something about ionic solubility, was also given no credit. Although it's possible the student had an idea that potassium ions were always soluble, that is not clear.

Appendix F

Partial Credit Awarded for Question 9 on Chemical Changes Pre/Posttest

Correct answer:

complete ionic equation:

$Ba^{2+}(aq) + 2I^-(aq) + 2Ag^+(aq) + 2NO_3^-(aq) \rightarrow 2AgI(s) + Ba^{2+}(aq) + 2NO_3^-(aq)$

net ionic equation:

$Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$
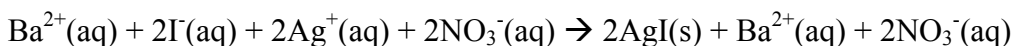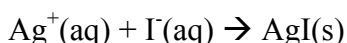
Point **deductions** for complete ionic equation and net ionic equation, each (deductions on each cannot exceed one point):

1) -.15 for any missing/incorrect state of matter (can only be docked once for this; even if more than one particle has missing/incorrect state of matter)

2) -.15 for each incorrect charge, but only -.10 for adding the correct charges on top of AgI(s) (maximum -.30)

3) -.15 for each incorrect subscript (maximum -.30)

4) -.15 for each incorrect coefficient (maximum -.30)

5) -.25 for each instance of writing what should be separate particles as part of a compound OR writing what should be a compound as separate particles

6) -.25 for including particles or compounds that should not be in the equation (such as having Ba^{2+} in the net ionic equation) OR leaving out particles or compounds that should be there (separate deduction for each particle)

7) -.20 for not reducing to smallest whole number ratio

Appendix G

IRB Documentation (Approval Letter)

Office of Research Compliance

Schroeder Complex, 102
P.O. Box 1881
Milwaukee, Wisconsin 53201-1881

P 414.288.7570
F 414.288.6281
W marquette.edu/researchcompliance

MARQUETTE
UNIVERSITY
Be The Difference.

September 17, 2012

Mr. Edwin O'Sullivan
Educational Policy and Leadership

Dear Mr. O'Sullivan:

Thank you for submitting your protocol number HR-2476 titled, "*Wiki Collaboration among Latino High School Chemistry Students.*" On September 17, 2012, the Marquette University Institutional Review Board granted exempt status for this protocol under Exemption Category #1: Normal Educational Practices and Settings.

Your IRB approved parent information sheet, student assent form, and teacher consent form are enclosed. Use stamped copies of these documents for consent purposes. Please note that the Spanish version of the parent information sheet is not stamped because the IRB is not able to verify the accuracy of the translation. You may use the Spanish version without an approval stamp.

You may proceed with your research. Your protocol has been granted exempt status as submitted. Any changes to your protocol *affecting participant risk* must be requested in writing by submitting an IRB Protocol Amendment Form. These changes must be reviewed and approved by the IRB before being initiated, except when necessary to eliminate apparent immediate hazards to the human subjects. **Any minor changes may be emailed to orc@mu.edu**. If there are any adverse events, please notify the Marquette University IRB immediately.

Please submit an IRB Final Report Form once this research project is complete. Submitting this form allows the Office of Research Compliance to close your file.

If you have any questions or concerns, please do not hesitate to contact me. Thank you for your time and cooperation.

Sincerely,

Amanda J. Ahrndt, RN, MS, MSN, CIM, CIP
IRB Manager

cc: Dr. Christopher Okunseri, IRB Chair
        Dr. Francesca Lopez, EDPL
        Ms. Sherri Lex, Graduate School

Enclosures (3)

Appendix H

IRB Documentation (Student Assent Form)

Protocol Number: HR-2476

MARQUETTE UNIVERSITY
ASSENT FORM FOR RESEARCH PARTICIPANTS
Wiki Collaboration among Latino High School Chemistry Students

Investigator(s): Edwin O'Sullivan, M.S., PhD. Candidate.

We are doing a research study. A research study is a special way to find out about something. We want to find out if and why wikis are effective at helping students learn chemistry.

You can be in this study if you want to. If you want to be in this study, you will be asked to meet with Mr. O'Sullivan for about 40-50 minutes with 2 or 3 other students and answer some questions about what you thought of the activity.

We want to tell you about some things that might happen to you if you are in this study. The only risk is that you might feel uncomfortable answering a question or two, such as one that asks your opinion of an explanation provided by a fellow group member or the teacher. If a question makes you uncomfortable you do not have to answer that question.

If you decide to be in this study, some good things might happen to you. As a result of answering the questions, and hearing what others have to say, you might come to a better understanding of the content. We might also find out things that will help future students.

When we are done with the study, we will write a report about what we found out. We won't use your name in the report. All the information you provide will be kept private.

It is your decision whether or not to be in the study. You do not have to be in this study if you don't want to. You can say "no" and nothing bad will happen. If you say "yes" now, but you want to stop later, that's okay too. If something about the study bothers you, you can stop being in the study. All you have to do is tell Mr. O'Sullivan you want to stop. If there is anything you don't like about being in the study, you should tell us and if we can, we will try to change it for you.

If you have any questions about the study, you can ask Mr. O'Sullivan or ▬▬▬▬ We will try to explain everything that is being done and why. Please ask us about anything you want to know.

If you want to be in this study, please sign and print your name.

I, _____, want to be in this research study.
(write your name here)

_____   _____
Sign your name here   (Date)

_____   _____
Investigator signature   (Date)

Appendix I

IRB Documentation (Teacher Consent Form)

Protocol Number: HR-2476

MARQUETTE UNIVERSITY
AGREEMENT OF CONSENT FOR RESEARCH PARTICIPANTS
Wiki Collaboration Among Latino High School Chemistry Students
Principal Investigator: Edwin O'Sullivan
Department of Educational Policy and Leadership

You have been invited to participate in this research study. Before you agree to participate, it is important that you read and understand the following information. Participation is completely voluntary. Please ask questions about anything you do not understand before deciding whether or not to participate.

PURPOSE: The purpose of this research study is to understand more about how high school chemistry students help each other learn, and how the teacher helps students learn, when doing a collaborative online activity known as a wiki. You will be one of approximately 12 participants in this research study.

PROCEDURES: You will be interviewed at the conclusion of each activity to get your impressions. The sessions will be audio recorded to ensure accuracy. The tapes will later be transcribed and destroyed after 3 years beyond completion of the study. For confidentiality purposes, your name will not be recorded. You will also be asked to keep a log of your communications with students that pertain to the activity topics.

DURATION: Your participation will consist of three 20 minutes interviews, plus a few minutes each day as needed to record communications with students.

RISKS: The risks associated with participation in this study are minimal and are no more than you would encounter in everyday life.

BENEFITS: The benefits associated with participation in this study include an opportunity to reflect on a new teaching strategy and consider its effectiveness.

CONFIDENTIALITY: All information you reveal in this study will be kept confidential. All your data will be assigned a pseudonym rather than using your real name or other information that could identify you as an individual. When the results of the study are published, you will not be identified by name. The data will be maintained indefinitely and may be used for future research purposes. Your research records may be inspected by the Marquette University Institutional Review Board or its designees, and (as allowable by law) state and federal agencies.

VOLUNTARY NATURE OF PARTICIPATION: Participating in this study is completely voluntary and you may withdraw from the study and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled. Should you wish to withdraw, all you need to do is inform the researcher, Ed O'Sullivan (414-727-0434 or edwin.osullivanjr@marquette.edu). If you decide to withdraw, there are no negative consequences whatsoever.

Page 1 of 2

Protocol Number: HR-2476

CONTACT INFORMATION: If you have any questions about this research project, you can contact the researcher, Ed O'Sullivan at 414-727-0434 (home) or 414-897-3232 (cell) or edwin.osullivanjr@marquette.edu. If you have questions or concerns you can contact Marquette University's Office of Research Compliance at (414) 288-7570.

I HAVE HAD THE OPPORTUNITY TO READ THIS CONSENT FORM, ASK QUESTIONS ABOUT THE RESEARCH PROJECT AND AM PREPARED TO PARTICIPATE IN THIS PROJECT.

_____	_____
Participant's Signature	Date
_____	
Participant's Name	
_____	_____
Researcher's Signature	Date

MARQUETTE
Approved
SEP 17 2012
IRB
UNIVERSITY

Appendix J

IRB Documentation (Parent Information Sheet)

Protocol Number: HR-2476

MARQUETTE UNIVERSITY
PARENT RESEARCH INFORMATION SHEET
Wiki Collaboration Among Latino High School Chemistry Students
Principal Investigator: Edwin O'Sullivan - Department of Educational Policy and Leadership

Your child has been invited to participate in a research interview. Whether or not your child participates will have no impact on his/her grades or standing at ███████████

PURPOSE: The purpose of this research study is to understand more about how high school chemistry students help each other learn, and how the teacher helps students learn, when doing a collaborative online activity known as a wiki. Your child will be one of approximately 12 participants in this research study.

PROCEDURES: The researcher is evaluating classroom activities in chemistry classes at your child's school. The researcher also wants to interview small groups of about four students about their experiences in chemistry class using a wiki. The interview will be audio taped to ensure accuracy. The tapes will later be transcribed and destroyed after three years beyond the completion of the study. For confidentiality purposes, your child's name will not be recorded.

DURATION: Your child's participation will consist of about 45 minutes of time.

RISKS: The risks associated with participation in this study include no more than your child would encounter in everyday life discussing classroom activities.

BENEFITS: The benefits associated with participation in this study are minimal. Perhaps your child will learn a bit more about chemistry during the interview as a result of discussing it with fellow students.

CONFIDENTIALITY: All information your child reveals in this study will be kept confidential. It is possible the data will be used in the future for related studies about how high school students best learn chemistry. Your child's research records may be inspected by the Marquette University Institutional Review Board or its designees and (as allowable by law) state and federal agencies.

COMPENSATION: As compensation for their participation, your child will receive a $10 iTunes gift card.

VOLUNTARY NATURE OF PARTICIPATION: Your child's participation in this study is completely voluntary and your child may withdraw from the study and stop participating at any time without penalty or loss of benefits to which your child is otherwise entitled. Should they wish to withdraw, all your child needs to do is inform their teacher, ███████ or the researcher, Ed O'Sullivan (414-727-0434 or edwin.osullivanjr@marquette.edu). If your child decides to withdraw, there are no negative consequences whatsoever.

CONTACT INFORMATION: If you have any questions about this research project, you can contact the researcher, Ed O'Sullivan at 414-727-0434 (home) or 414-897-3232 (cell) or at edwin.osullivanjr@marquette.edu. You can also contact your child's teacher, ████████████████████████ If you prefer to communicate in Spanish, you can contact the ██████████████████████████ and they will relay your questions to the researcher. At any time, you can request an opportunity to review the questions which will be asked of the students during the interview. If you have questions or concerns about your child's rights as a research participant, you can contact Marquette University's Office of Research Compliance at (414) 288-7570.

STUDENTS WILL HAVE AN OPPORTUNITY TO VOLUNTEER FOR THIS RESEARCH INTERVIEW. IF YOU DO NOT WANT YOUR CHILD TO PARTICIPATE IN THIS RESEARCH INTERVIEW CONTACT YOUR CHILD'S TEACHER ███████ OR THE RESEARCHER (CONTACT INFORMATION ABOVE).

Universidad de Marquette
HOJA DE INFORMACIÓN SOBRE LOS RESULTADOS DE INVESTIGACION DE PADRES
Wiki Colaboración entre los estudiantes latinos de secundaria de Química
Investigador principal: Edwin O'Sullivan - Departamento de Política Educativa y Liderazgo

Su hijo ha sido invitado a participar en una entrevista de investigación. Sea o no que su hijo participe no tendrá ningún impacto en sus calificaciones en ██████████████

OBJETIVO: El objetivo de este estudio de investigación es de entender más acerca de cómo los estudiantes de química de escuela secundaria ayudan mutuamente a aprender, y cómo el maestro ayuda a los estudiantes a aprender, cuando se realiza una actividad de colaboración en línea conocido como un wiki. Su hijo será uno de los aproximadamente 12 participantes en este estudio.

PROCEDIMIENTOS: El investigador está evaluando las actividades del aula en las clases de química en la escuela de su hijo. El investigador también quiere entrevistar a pequeños grupos de alrededor de cuatro estudiantes acerca de sus experiencias en la clase de química mediante un wiki. La entrevista será grabada en audio para asegurar la exactitud. Las cintas más tarde se transcribirá y destruidos después de tres años más allá de la terminación del estudio. Por razones de confidencialidad, el nombre de su hijo no se grabará.

DURACIÓN: La participación de su hijo estará formada por cerca de 45 minutos de tiempo.

RIESGOS: Los riesgos asociados con la participación en este estudio serán los mismos riesgos de cualquier salón en la vida cotidiana.

BENEFICIOS: Los beneficios asociados con la participación en este estudio son mínimos. Tal vez su hijo aprenderá un poco más sobre la química durante la entrevista.

CONFIDENCIALIDAD: Toda la información que su hijo pone de manifiesto en este estudio será confidencial. Es posible que los datos serán utilizados en el futuro para los estudios relacionados acerca de cómo los estudiantes de secundaria aprenden mejor química. Los registros de su hijo de investigación pueden ser inspeccionados por la Junta de Revisión Institucional de la Universidad de Marquette o sus designados y (como permitido por la ley) las agencias estatales y federales.

COMPENSACIÓN: Como compensación por su participación, su hijo recibirá una tarjeta de regalo de iTunes por $10.

NATURALEZA VOLUNTARIA DE PARTICIPACIÓN: La participación de su hijo en este estudio es completamente voluntaria y su hijo puede retirarse del estudio y dejar de participar en cualquier momento sin pérdida de beneficios a los que de otro modo el niño tiene derecho. En caso de que desee retirar, su hijo tiene que informar a su maestra, la ██████ o el investigador, Ed O'Sullivan (414-727-0434 o edwin.osullivanjr@marquette.edu). Si su hijo decide retirarse, no hay consecuencias negativas de ningún tipo.

INFORMACIÓN DE CONTACTO: Si usted tiene alguna pregunta acerca de este proyecto de investigación, puede comunicarse con el investigador, Ed O'Sullivan en 414-727-0434 (casa) o 414-897-3232 (celular) o en edwin.osullivanjr@marquette.edu . También puede comunicarse con el maestro de su hijo, ██████████████ ████████████████████████ Si prefiere comunicarse en español, puede comunicarse con la oficina del ████████████████████ sus preguntas seran enviadas con el investigador. En cualquier momento, usted puede solicitar la oportunidad de revisar las preguntas que se le formularán de los estudiantes durante la entrevista. Si tiene preguntas o inquietudes acerca de los derechos de su hijo como participante de una investigación, puede comunicarse con la Oficina de la Universidad Marquette de Cumplimiento de Investigación al (414) 288- 7570.

Los estudiantes tendrán la oportunidad de ser voluntarios para esta entrevista de INVESTIGACIÓN. SI USTED NO DESEA QUE SU HIJO PARTICIPE EN ESTA ENTREVISTA contacte la ████████ al investigador (el numero lo encontrara arriba).

Appendix K

IRB Documentation (Internet Access Survey Approval Letter)

RE: followup survey

Ahrndt, Amanda
Sent: Thursday, March 07, 2013 10:16 AM
To: O'Sullivan Jr., Edwin
Cc: Lopez, Francesca

Hi Ed,

Thank you for letting us know about the survey. Because you are asking the questions as part of learning about normal educational practices no further action is necessary. Your protocol remains exempt and you may administer the survey.

If you have any questions please do not hesitate to contact me.

Good luck with the completion of your study.

Best,
Amanda

Appendix L

Teacher "Cheat Sheet" for Bonding Activity

Teacher "Cheat Sheet" for Bonding Wiki

With the exception of specific wiki group or control group activities (planned or otherwise), provide the same instructions to both treatment and control groups (same class notes, same homework problems, same in-class practice problems, etc…).

First Day	Introduce Activity to Entire Class (35-40 minutes)	Ed will observe and audio record.
		1. Share what we learned from first activity (from the actual pages and from interviewing students): a. Students liked using the technology b. Students liked the opportunity to be creative (add your own images, video etc…) but it was challenging at times c. Some explanations were very creative, articulate, and accurate! d. Students found it difficult collaborating on a wiki; face-to-face collaboration preferred, including more whole-class discussion e. **Very little** editing of someone else's work was done (even though the rubric called for it) f. Students felt the teacher should provide feedback before edits are made by others g. Having a detailed rubric was both a welcome guide (lets you know what to do and when to do it) and a hindrance (stifles creativity; too many due dates)
		2. Solicit comments from students on the above (but we need to keep it relatively brief so I would just ask if there is anything they would like to add; don't get bogged down with everyone putting their two cents in)
		3. Highlight the changes we've made based on the results of the first activity: a. You won't be forced to make changes to something you feel is already good enough b. Teacher feedback will occur earlier and before editing other's work is expected c. There will be some whole class discussion of a topic today
		4. But most things are the same. a. Encourage to give wiki collaboration at least one more try (try to make the general point that we agree that it is very challenging! But that's largely because it's unfamiliar, and the world is headed this way (it's already there!). Describe benefits:

i. Develop *21st century* listening and communication skills (working in teams, *using technology*, is part of real world *today*!)

Who uses wikis?

Several businesses, government agencies and schools which purportedly use wikis were listed here. The list is hidden since the credibility of the sources which provided the information is unknown.

ii. Group members notice mistakes you missed
iii. Learn to treat other's opinions with respect
iv. Promotes deeper understanding of content when you have to justify your answers to others
v. Feeling hesitant to edit someone else's work is a common feeling among wiki participants. Don't let this stop you from doing it! You can explain why you made the change in the discussion forum or face-to-face.
vi. Don't feel offended if someone edit's your work. Consider discussing with your fellow group member in discussion forum or face-to-face.

b. There are still four topics and there is still a detailed rubric.
i. Show how the four topics are now on different pages this time
ii. Have a whole class discussion about **Topic 4.** Read topic from Wiki page and brainstorm with them with questions like, perhaps, "Let's brainstorm. What's a creative way to describe to someone that when atoms come together to form a bond, they release energy and become more stable?" If no one offers an example, consider saying something like "Well, forget about atoms and bonds for a moment. What's an example from everyday life that when things come together they become more stable?" Assuming they now say something, perhaps now brainstorm on how to make it more creative? And ask if there are any shortcomings to their analogy. Then consider asking the class for one more example. Don't spend more than 5-10 minutes on this. The idea here is

		to get them **started** thinking about it.
		   iii. Go over details of the rubric emphasizing the differences from last time, which are:
		-The expectations for Topics 3 and 4 are slightly different than Topics 1 and 2; Topics 3 and 4 have more emphasis on creativity (fyi, this is because I learned from grading the trial run that the way some topics are phrased, pretty much all the chemistry was already provided and coming up with a creative explanation was more important for some)
		-Once the collaborative phase gets into full swing after the midpoint discussions, they are still required to make one significant contribution to each topic. However, if they feel there are no improvements needed to a particular topic, it is acceptable to provide another example (and explanation to accompany).
		   iv. Use of the Wiki Discussion Forum to explain what you did or reply to posts is still highly encouraged, but is now extra credit.

		5. Expectations in a nutshell
		  a. First develop wiki topic mostly individually (remind of initial contribution deadline, and midpoint deadline when full first draft is due). Emphasize to focus on the first section of the rubric.
		  b. Develop all four topics collaboratively after midpoint (remind of final due date deadline). Emphasize to focus on the second page of the rubric.
		     i. Remind that they can replace their score on the first activity with their score on this one
		     ii. Remind them they can communicate in Spanish

	Small Group Discussion (8-10 minutes)	1. Students should read topics (and discuss if time) and assign one topic to each group member. 2. Collect sheets with who was assigned what topic 3. Give students login information.
	CONTROL GROUPS	Do any activity with the control group that falls into the category of your "normal" instruction. This can include assigning end-of-chapter HW problems to work on, as you suggested before. Whatever you choose to do, keep a fairly detailed account of what you covered (for example, if you assign problems, make note of which ones you assigned) so I'll have a record.

Day after the First Day	email or in class reminder	Remind students in class or by email of the initial contribution deadline
Day after Initial Contribution Deadline	send email	Monitor wiki to check for initial contributions. Send email to students who have not begun yet. (I can do this for you to save you time. That is, check for participation, let you know by email, and then you would just have to copy and paste (edit if desired) and send the email. Please you blind copy me on this and all email communications that are wiki related.)
Between First Day and Midpoint Meeting	Monitor wiki as time permits	As time permits, provide feedback/encouragement to students via face-to-face, email, or discussion forum. I'll likely send daily emails if I think there is anything noteworthy worth mentioning. You can act on them the way you see fit and/or have time for.
	Daily Log	Keep daily log of any wiki related communication with students.
Day Before Midpoint Meeting	Discussion Forum Post	*Before* midpoint meeting, post detailed scaffolding for each topic in each wiki (i.e. a total of 16 posts). Don't address to a particular person since its advice intended for the entire group. (I'll compose these for you to save you time, focusing on metacognitive scaffolding, i.e. encouraging them to reflect and reconsider particular weaknesses. I'll send you my email early the day before the midpoint meeting. You can review, edit, and then post in discussion forum for each topic. **The key is to get it posted in time for the students to discuss your feedback during their midpoint meeting.**
	Send bulk email	Emphasize that if they have time before the midpoint meeting they should login and read all the topics. (or mention this in class). Emphasize that at the midpoint meeting they should: 1) have each person read their first draft of their topic 2) read together the comments you posted for each topic 3) Give yourself a score (paying special attention to what is missing that the first page of the rubric called for) 4) discuss ways of improving each topic based on teachers comments in discussion forum, their

		opinions, and the final criteria for each topic (second page of rubric); also emphasize that from this point on it is a collaborative activity and the **entire** group is responsible for improving **every** topic Specifically, remind them: 1) each member is required to make one significant contribution to each topic not initially assigned to them; if they feel that there is nothing to add, then the least they need to do is add an additional example (with explanation to support it) 2) everyone in the group gets the same final score for each topic, so it's in everyone's best interest to review the rubric and make sure every topic meets all the criteria before the final due date 3) they get to replace their score on the previous wiki activity with this one (again, if you support that) (I will compose this email for you and send it to you the same time I send the discussion post email)
Midpoint Meeting (at approx. 1– 2 weeks)		In computer lab, students will discuss all four topics in their small groups, focusing on how to act on your scaffolding from the recent discussion post. Reiterate to students the contents of the bulk email you sent the previous day, including to give themselves a midpoint score. Have each group sit in a different corner of the computer lab and, initially, only look at one computer for their discussion. I will observe, audio record, and video record (video record is pending IRB approval) one group; and audio record three other groups.
	CONTROL GROUPS	Do any activity with the control group that falls into the category of your "normal" instruction. This can include assigning end-of-chapter HW problems to work on, as you suggested before. Whatever you choose to do, keep a fairly detailed account of what you covered (for example, if you assign problems, make note of which ones you assigned) so I'll have a record.
Between Midpoint and Final Due Date	Monitor wiki as time permits	As time permits, provide feedback/encouragement to students via face-to-face, email, or discussion forum. I'll likely send daily emails if I think there is anything noteworthy worth mentioning. You can act on them the way you see fit and/or have time for.
	Daily Log	Keep daily log of any wiki related communication with students.
	Recruit	Recruit about 6-8 students for post activity focus group (based on student wiki activity, I'll recommend

	Students	some students). **Give volunteers parent information sheet, at least a week before focus group, to bring home to parents (it doesn't need to be returned with a signature).** Remind them they will get $10 iTunes gift card.
3-4 days before final due date	Discussion Forum Post	Post detailed scaffolding for each topic in each wiki (i.e. a total of 16 posts). Don't address to any particular person. (I will compose the discussion post, focusing on metacognitive scaffolding (i.e. encouraging them to reflect and reconsider particular weaknesses). I'll send you the post by email the day before. You can review, edit, and then post in discussion forum for each topic)
	Send bulk email	Send students bulk email to remind them: 1) to read your discussion forum postings (*all of the topics* in their wiki, not just the one for their initial topic) 2) if they haven't already done so, to make at least one significant contribution to each topic not initially assigned to them; and if they can't find something to improve on, to add an additional example (with an explanation) 3) everyone in the group gets the same final score for each topic, so it's in everyone's best interest to review the rubric and make sure every topic is the best it can be 4) they get to replace their score on the initial wiki activity with this one
Day before final due date	Email in or in-class	Remind students by email or in class that wikis are due at midnight the next day
At least two days before Unit Exam (at approx. 3 weeks)	Wikis due	Final wikis due at prior midnight
	Posttest	Administer as soon as possible after wikis due (Ed will make copies of posttest and periodic table) Give students periodic table handout to look at during test

		Remind students of how to answer two-tiered questions (i.e. you need to circle **both** the number for the answer and the letter for the reason for the answer). Show them a sample (I'll provide one. On transparency probably.) Give students enough time to consider thoughtfully the questions but I don't think you need a whole period. It will only be 10 questions each time. Probably 20 minutes is good. Sort of play it by ear based on whether or not students think they need more time. Give an incentive of a half-point extra credit on the unit exam for each correct answer. Just something minimal, but enough to encourage them to try their best. Of course, do this for wiki class and both control classes as well. I'll observe the classes (treatment group and two control groups) and take the tests when the class is over so I can copy them, grade them that night, and get them back to you the next day so you can use it for exam review.
Within several days of Posttest	Focus Group	Ed will do Focus Group (one group of about 6-8 students each time; about 45-55 minutes) **Students first asked to read and sign Student Assent Form.**
	Teacher Interview	I'll interview you for about 20-30 minutes; you'll also need to sign a consent form.
	Daily Log	Submit your daily log of communications

Appendix M

Teacher "Cheat Sheet" for Physical Changes Activity

Teacher "Cheat Sheet" for Physical Changes Wiki

(comments in red indicate changes from the Bonding "Cheat Sheet")

With the exception of specific wiki group or control group activities (planned or otherwise), provide the same instructions to both treatment and control groups (same class notes, same homework problems, same in-class practice problems, etc…).

Below I make a reference to the "first activity". Remember, from the perspective of Fourth Hour students, that is the trial run activity, not the Bonding activity. In general, to keep things as consistent as possible for all three interventions, don't make references to the Bonding activity. That is, please stay away from statements like "We learned from the First Hour class that those who put the time in, and followed the rubric criteria, did much better on both the activity and the unit exam". However, feel free to motivate them with references to the trial run activity, such as "If you improve your performance on this activity, compared to the first activity, you can replace your score from that first activity".

First Day	Introduce Activity to Entire Class (25-30 minutes)	Ed will observe and audio record.

		1. Share what we learned from first activity (from the actual pages and from interviewing students):
		  a. Students liked using the technology
		  b. Students liked the opportunity to be creative (add your own images, video etc…) but it was challenging at times
		  c. Some explanations were very creative, articulate, and accurate!
		  d. Students found it difficult collaborating on a wiki; face-to-face collaboration preferred, including more whole-class discussion
		  e. **Very little** editing of someone else's work was done (even though the rubric called for it)
		  f. Students felt the teacher should provide feedback before edits are made by others
		  g. Having a detailed rubric was both a welcome guide (lets you know what to do and when to do it) and a hindrance (stifles creativity; too many due dates)

		2. Solicit comments from students on the above (but we need to keep it relatively brief so I would just ask if there is anything they would like to add; don't get bogged down with everyone putting their two cents in)

		3. Highlight the changes we've made based on the results of the first activity:
		  a. You won't be forced to make changes to something you feel is already good enough
		  b. Teacher feedback will occur earlier and before editing other's work is expected
		  c. There will be some whole class discussion of a topic today

		4. But most things are the same.
		  a. Encourage to give wiki collaboration at least one more try (try to make the general point that we agree that it is very challenging! But that's largely because it's unfamiliar, and the world is headed this way (it's already there!). Describe benefits:
		
		    i. Develop *21st century* listening and communication skills (working in teams, *using technology*, is part of real world *today!*)
		
		    Who uses wikis?

Several businesses, government agencies and schools which purportedly use wikis were listed here. The list is hidden since the credibility of the sources which provided the information is unknown.

  ii. Group members notice mistakes you missed
  iii. Learn to treat other's opinions with respect
  iv. Promotes deeper understanding of content when you have to justify your answers to others
  v. Feeling hesitant to edit someone else's work is a common feeling among wiki participants. Don't let this stop you from doing it! You can explain why you made the change in the discussion forum or face-to-face.
  vi. Don't feel offended if someone edit's your work. Consider discussing with your fellow group member in discussion forum or face-to-face.
 b. There are still four topics and there is still a detailed rubric.
  i. Show how the four topics are now on different pages this time
  ii. Show the new link "Resources Page" where they can find links and a video they can use (but they don't HAVE to use these)
  iii. Have a whole class discussion about **Topic 1**. Read the introduction to them on the top of the page (or just give them the highlights). Then solicit their input on answering the question in section "a". Finally (*time permitting; since Monday is a shorter period, omit this if needed; we need to have time at the end to make sure they remember their logins and they each choose a topic*), brainstorm a bit on how to creatively represent the concept that physical changes, unlike chemical changes, do NOT involve a change in composition. If no one offers an example, consider saying something like "Well, forget about atoms and bonds for a moment. What's an example from everyday life of something undergoing a significant change, and at the same time each individual component retaining its basic characteristics". (Some examples that come to mind: 1) Members of a marching band who are clustered together but then disperse in another formation. Each member still

<table>
<tr>
<td></td>
<td></td>
<td colspan="2">has their original instrument, uniform etc…2) Football players in a huddle who then break huddle to line up for the play. Each player still has the same role as in the huddle, same uniform etc…3) Black Friday shoppers who are huddle together near the store entrance, only to disperse to different parts of the store once the store opens. Each shopper is still the same basic person before and after the doors open.) Assuming they now say something, perhaps now brainstorm on how to make it more creative? And ask if there are any shortcomings to their analogy (for example, in the shopping analogy, it's not as good an analogy if all the shoppers rush to the same part of the store to get the same product and thus are still all huddled together). Don't spend more than 5-10 minutes on this. The idea here is to get them **started** thinking about it.

   iv. Go over details of the rubric emphasizing the differences from last time, which are:

-The expectations for Topic 3 is slightly different than Topics 1, 2, and 4; Topic 3 has slightly more emphasis on creativity

-Once the collaborative phase gets into full swing after the midpoint discussions, they are still required to make one significant contribution to each topic. However, if they feel there are no improvements needed to a particular topic, it is acceptable to provide another example (and explanation to accompany).

   v. Use of the Wiki Discussion Forum to explain what you did or reply to posts is still highly encouraged, but is now extra credit.</td>
</tr>
<tr>
<td></td>
<td></td>
<td colspan="2">5. Expectations in a nutshell

  a. First develop wiki topic mostly individually (remind of initial contribution deadline, and midpoint deadline when full first draft is due). Emphasize to focus on the first section of the rubric (top of first page of rubric).

  b. Develop all four topics collaboratively after midpoint (remind of final due date deadline). Emphasize to focus on the second and third sections of the rubric (bottom of first page and all second page).

     i. Remind that they can replace their score on the first activity with their score on this one

    ii. Remind them they can communicate in Spanish</td>
</tr>
</table>

	Small Group Discussion (8-10 minutes)	1. Have students go to a computer to make sure they can log in. 2. Group members decide who gets what topic initially and write their name on top of the respective wiki page. 3. (*Time permitting*) Discuss ideas about the topics.
	CONTROL GROUPS	Since last time (Bonding activity) you practiced HW-style problems with the control groups, please do so again this time to stay consistent.
Day after the First Day	email or in class reminder	Remind students in class or by email of the initial contribution deadline
Day after Initial Contribution Deadline	send email	Monitor wiki to check for initial contributions. Send email to students who have not begun yet. (I can do this for you to save you time. That is, check for participation, let you know by email, and then you would just have to copy and paste (edit if desired) and send the email. Please blind copy me on this and all email communications that are wiki related.)
Between First Day and Midpoint Meeting	Monitor wiki as time permits	As time permits, provide feedback/encouragement to students via face-to-face, email, or discussion forum. I'll likely send daily emails if I think there is anything noteworthy worth mentioning. You can act on them the way you see fit and/or have time for.
	Daily Log	Keep daily log of any wiki related communication with students.
Day Before Midpoint Meeting	Discussion Forum Post	*Before* midpoint meeting, post detailed scaffolding for each topic in each wiki (i.e. a total of 16 posts). Don't address to a particular person since its advice intended for the entire group. (I'll compose these for you to save you time, focusing on metacognitive scaffolding, i.e. encouraging them to reflect and reconsider particular weaknesses. I'll send you my email early the day before the midpoint meeting. You can review, edit, and then post in discussion forum for each topic.) **The key is to get it posted in time for the students to discuss your feedback during their midpoint meeting.**
	Send bulk email	Emphasize that if they have time before the midpoint meeting they should login and read all the topics. (or mention this in class).

		Emphasize that at the midpoint meeting they should: 1) have each person read their first draft of their topic 2) read together the comments you posted for each topic 3) Give yourself a score (paying special attention to what is missing that the final criteria (second page of rubric) calls for) 4) discuss ways of improving each topic based on teachers comments in discussion forum, their opinions, and the final criteria for each topic (second page of rubric); also emphasize that from this point on it is a collaborative activity and the **entire** group is responsible for improving **every** topic Specifically, remind them: 1) each member is required to make one significant contribution to each topic not initially assigned to them; if they feel that there is nothing to add, then the least they need to do is add an additional example (with explanation to support it) 2) everyone in the group gets the same final score for each topic, so it's in everyone's best interest to review the rubric and make sure every topic meets all the criteria before the final due date. (This also means they are encouraged to make edits based on their original topic as well. To stay consistent with the first intervention, don't remind students of this any more or any less then you did before. However, if a student asks you about it, then by all means encourage them to improve on their original topic in addition to the others.) 3) they get to replace their score on the previous wiki activity with this one (I will compose this email for you and send it to you the same time I send the discussion post email)
Midpoint Meeting (at approx. 1–2 weeks)		In computer lab, students will discuss all four topics in their small groups, focusing on how to act on your scaffolding from the recent discussion post. Reiterate to students the contents of the bulk email you sent the previous day, including to give themselves a midpoint score. Have each group sit in a different corner of the computer lab and, initially, only look at two computers for their discussion (please emphasize the importance of going to a corner, and use the two computers at the end of the row). I will observe and audio record all groups.
	CONTROL	Since last time (Bonding activity) you practiced HW-style problems with the control groups, please do

	GROUPS	so again this time to stay consistent.
Between Midpoint and Final Due Date	Monitor wiki as time permits	As time permits, provide feedback/encouragement to students via face-to-face, email, or discussion forum. I'll likely send daily emails if I think there is anything noteworthy worth mentioning. You can act on them the way you see fit and/or have time for.
	Daily Log	Keep daily log of any wiki related communication with students.
3-4 days before final due date	Discussion Forum Post	Post detailed scaffolding for each topic in each wiki (i.e. a total of 16 posts). Don't address to any particular person. (I will compose the discussion post, focusing on metacognitive scaffolding (i.e. encouraging them to reflect and reconsider particular weaknesses. I'll send you the post by email the day before. You can review, edit, and then post in discussion forum for each topic). I think it's important we get these up no later than sometime on the Friday before the final due date.
	Send bulk email	Send students bulk email to remind them: 1) to read your discussion forum postings (*all of the topics* in their wiki, not just the one for their initial topic) 2) if they haven't already done so, to make at least one significant contribution to each topic not initially assigned to them; and if they can't find something to improve on, to add an additional example (with an explanation) 3) everyone in the group gets the same final score for each topic, so it's in everyone's best interest to review the rubric and make sure every topic is the best it can be; (And again, if someone brings it up, and remind them they are welcome to improve on their initial topic as well) 4) they get to replace their score on the initial wiki activity with this one
Day before final due date	Email in or in-class	Remind students by email or in class that wikis are due at midnight the next day
At least two days before	Wikis due	Final wikis due at prior midnight

Unit Exam (at approx. 3 weeks)		
	Posttest	Administer as soon as possible after wikis due (Ed will make copies of posttest and periodic table) Give students periodic table handout to look at during test Remind students of how to answer two-tiered questions (i.e. you need to circle **both** the number for the answer and the letter for the reason for the answer). Show them a sample (I'll provide one) Give students enough time to consider thoughtfully the questions but I don't think you need a whole period. Probably 20 minutes is good. Sort of play it by ear based on whether or not students think they need more time. Give an incentive of a half-point extra credit on the unit exam for each correct answer. Just something minimal, but enough to encourage them to try their best. Of course, do this for wiki class and both control classes as well. I'll observe the classes (treatment group and two control groups) and take the tests when the class is over so I can copy them, grade them that night, and get them back to you the next day so you can use it for exam review.
Within several days of Posttest	Recruit Students (this was just moved to the end)	Recruit about 6-8 students for post activity focus group (based on student wiki activity, I'll recommend some students). **Give volunteers parent information sheet, at least a week before focus group, to bring home to parents (it doesn't need to be returned with a signature).** Remind them they will get $10 iTunes gift card.
	Focus Group	Ed will do Focus Group (one group of about 6-8 students each time; about 45-55 minutes) **Students first asked to read and sign Student Assent Form.**
	Teacher Interview	I'll interview you for about 20-30 minutes; you'll also need to sign a consent form.
	Daily Log	Submit your daily log of communications

Appendix N

Teacher "Cheat Sheet" for Chemical Changes Activity

Teacher "Cheat Sheet" for Chemical Changes Wiki

(comments in red indicate changes from the Physical Changes "Cheat Sheet")

With the exception of specific wiki group or control group activities (planned or otherwise), provide the same instructions to both treatment and control groups (same class notes, same homework problems, same in-class practice problems, etc…).

Below I make a reference to the "first activity". Remember, from the perspective of Sixth Hour students, that is the trial run activity, not the Bonding or Physical Changes activity. In general, to keep things as consistent as possible for all three interventions, don't make references to the Bonding or Physical Changes activity. That is, please stay away from statements like "We learned from the First Hour class that those who put the time in, and followed the rubric criteria, did much better on both the activity and the unit exam". However, feel free to motivate them with references to the trial run activity, such as "If you improve your performance on this activity, compared to the first activity, you can replace your score from that first activity".

First Day	Introduce Activity to Entire Class (30-35 minutes)	Ed will observe and audio record.
		1. Share what we learned from first activity (from the actual pages and from interviewing students): a. Students liked using the technology b. Students liked the opportunity to be creative (add your own images, video etc…) but it was challenging at times c. Some explanations were very creative, articulate, and accurate! d. Students found it difficult collaborating on a wiki; face-to-face collaboration preferred, including more whole-class discussion e. **Very little** editing of someone else's work was done (even though the rubric called for it) f. Students felt the teacher should provide feedback before edits are made by others g. Having a detailed rubric was both a welcome guide (lets you know what to do and when to do it) and a hindrance (stifles creativity; too many due dates)
		2. Solicit comments from students on the above (but we need to keep it relatively brief so I would just ask if there is anything they would like to add; don't get bogged down with everyone putting their two cents in)
		3. Highlight the changes we've made based on the results of the first activity: a. You won't be forced to make changes to something you feel is already good enough b. Teacher feedback will occur earlier and before editing other's work is expected c. There will be some whole class discussion of a topic today
		4. But most things are the same. a. Encourage to give wiki collaboration at least one more try (try to make the general point that we agree that it is very challenging! But that's largely because it's unfamiliar, and the world is headed this way (it's already there!). Describe benefits: i. Develop 21st century listening and communication skills (working in teams, *using technology*, is part of real world *today*!) Who uses wikis?

Several businesses, government agencies and schools which purportedly use wikis were listed here. The list is hidden since the credibility of the sources which provided the information is unknown.

    ii. Group members notice mistakes you missed
    iii. Learn to treat other's opinions with respect
    iv. Promotes deeper understanding of content when you have to justify your answers to others
    v. Feeling hesitant to edit someone else's work is a common feeling among wiki participants. Don't let this stop you from doing it! You can explain why you made the change in the discussion forum or face-to-face.
    vi. Don't feel offended if someone edit's your work. Consider discussing with your fellow group member in discussion forum or face-to-face.
b. There are still four topics and there is still a detailed rubric.
    i. Show how the four topics are now on different pages this time
    ii. Have a whole class discussion about **Topic 4**. Read the introduction to them on the top of the page (or just give them the highlights). Then solicit their input on answering the question in section "a". Finally, brainstorm a bit on how to creatively represent the concept that spectator ions exist as independent ions before and after a precipitation reaction (i.e. section "c" for Topic 4). If no one offers an example, consider saying something like "Well, forget about ions and reactions for a moment. What's an example from everyday life of something that exists independent of other things that it's similar to, even as changes go on around it? (Some examples that come to mind: 1) A small independent country that retains its independence even with many neighboring, more powerful countries at war around it, 2) A college football team like Notre Dame that retains its independence even as many conferences realign, 3) A person who goes from being single, to being in a relationship, but they very much keep their independence in terms of their hobbies, points of view, etc…) Assuming they now say something, perhaps

		now brainstorm on how to make it more creative? And ask if there are any shortcomings to their analogy (for example, in the small independent country analogy, a shortcoming of using it for an analogy of spectator ions is that there is only ONE country in the example, and in precipitation reactions, there are always TWO spectator ions, one anion and one cation). Don't spend more than 5-10 minutes on this. The idea here is to get them **started** thinking about it. iii. Go over details of the rubric emphasizing the differences from last time, which are: -The expectations for the four topics are similar, but not exactly the same (for example, for Topic 3, creativity is a bit more important than the other three). Remind them to look at the rubric carefully. -Once the collaborative phase gets into full swing after the midpoint discussions, they are still required to make one significant contribution to each topic. However, if they feel there are no improvements needed to a particular topic, it is acceptable to provide another example (and explanation to accompany). iv. Use of the Wiki Discussion Forum to explain what you did or reply to posts is still highly encouraged, but is now extra credit.

		5. Expectations in a nutshell
		  a. First develop wiki topic mostly individually (remind of initial contribution deadline, and midpoint deadline when full first draft is due). Emphasize to focus on the first section of the rubric (top of first page of rubric).
		  b. Develop all four topics collaboratively after midpoint (remind of final due date deadline). Emphasize to focus on the second and third sections of the rubric (bottom of first page and all second page).
		    i. Remind that they can replace their score on the first activity with their score on this one
		    ii. Remind them they can communicate in Spanish

	Small Group Discussion (10-15	1. Have students go to a computer to make sure they can log in. 2. Group members decide who gets what topic initially and write their name on top of the respective wiki page. 3. (*Time permitting*) Discuss ideas about the topics.

	minutes)	
	CONTROL GROUPS	Since the last two times (Bonding activity and Physical Changes activity) you practiced HW-style problems with the control groups, please do so again this time to stay consistent.
Day after the First Day	email or in class reminder	Remind students in class or by email of the initial contribution deadline
Day after Initial Contribution Deadline	send email	Monitor wiki to check for initial contributions. Send email to students who have not begun yet. (I can do this for you to save you time. That is, check for participation, let you know by email, and then you would just have to copy and paste (edit if desired) and send the email. Please blind copy me on this and all email communications that are wiki related.)
Between First Day and Midpoint Meeting	Monitor wiki as time permits	As time permits, provide feedback/encouragement to students via face-to-face, email, or discussion forum. I'll likely send daily emails if I think there is anything noteworthy worth mentioning. You can act on them the way you see fit and/or have time for.
	Daily Log	Keep daily log of any wiki related communication with students.
Day Before Midpoint Meeting	Discussion Forum Post	*Before* midpoint meeting, post detailed scaffolding for each topic in each wiki (i.e. a total of 16 posts). Don't address to a particular person since its advice intended for the entire group. (I'll compose these for you to save you time, focusing on metacognitive scaffolding, i.e. encouraging them to reflect and reconsider particular weaknesses. I'll send you my email early the day before the midpoint meeting. You can review, edit, and then post in discussion forum for each topic.) **The key is to get it posted in time for the students to discuss your feedback during their midpoint meeting.**
	Send bulk email	Emphasize that if they have time before the midpoint meeting they should login and read all the topics. (or mention this in class). Emphasize that at the midpoint meeting they should: 1) have each person read their first draft of their topic 2) read together the comments you posted for each topic

		3) Give yourself a score (paying special attention to what is missing that the final criteria (second page of rubric) calls for) 4) discuss ways of improving each topic based on teachers comments in discussion forum, their opinions, and the final criteria for each topic (second page of rubric); also emphasize that from this point on it is a collaborative activity and the **entire** group is responsible for improving **every** topic Specifically, remind them: 1) each member is required to make one significant contribution to each topic not initially assigned to them; if they feel that there is nothing to add, then the least they need to do is add an additional example (with explanation to support it) 2) everyone in the group gets the same final score for each topic, so it's in everyone's best interest to review the rubric and make sure every topic meets all the criteria before the final due date. (This also means they are encouraged to make edits to their original topic as well. To stay consistent with the first two interventions, don't remind students of this any more or any less then you did before. However, if a student asks you about it, then by all means encourage them to improve on their original topic in addition to the others.) 3) they get to replace their score on the previous wiki activity with this one (I will compose this email for you and send it to you the same time I send the discussion post email)
Midpoint Meeting (at approx. 1– 2 weeks)		In computer lab, students will discuss all four topics in their small groups, focusing on how to act on your scaffolding from the recent discussion post. Reiterate to students the contents of the bulk email you sent the previous day, including to give themselves a midpoint score. Have each group sit in a different corner of the computer lab and, initially, only look at two computers for their discussion (please emphasize the importance of going to a corner, and use the two computers at the end of the row). I will observe and audio record all groups.
	CONTROL GROUPS	Since last two times (Bonding activity and Physical Changes activity) you practiced HW-style problems with the control groups, please do so again this time to stay consistent.
Between Midpoint	Monitor wiki as time	As time permits, provide feedback/encouragement to students via face-to-face, email, or discussion forum. I'll likely send daily emails if I think there is anything noteworthy worth mentioning. You can

and Final Due Date	permits	act on them the way you see fit and/or have time for.
	Daily Log	Keep daily log of any wiki related communication with students.
3-4 days before final due date	Discussion Forum Post	Post detailed scaffolding for each topic in each wiki (i.e. a total of 16 posts). Don't address to any particular person. (I will compose the discussion post, focusing on metacognitive scaffolding (i.e. encouraging them to reflect and reconsider particular weaknesses. I'll send you the post by email the day before. You can review, edit, and then post in discussion forum for each topic).
	Send bulk email	Send students bulk email to remind them: 1) to read your discussion forum postings (*all of the topics* in their wiki, not just the one for their initial topic) 2) if they haven't already done so, to make at least one significant contribution to each topic not initially assigned to them; and if they can't find something to improve on, to add an additional example (with an explanation) 3) everyone in the group gets the same final score for each topic, so it's in everyone's best interest to review the rubric and make sure every topic is the best it can be; (And again, if someone brings it up, and remind them they are welcome to improve on their initial topic as well) 4) they get to replace their score on the initial wiki activity with this one
Day before final due date	Email in or in-class	Remind students by email or in class that wikis are due at midnight the next day
At least two days before Unit Exam (at approx. 3 weeks)	Wikis due	Final wikis due at prior midnight
	Posttest	Administer as soon as possible after wikis due (Ed will make copies of posttest and periodic table)

		Give students periodic table handout to look at during test Remind students of how to answer two-tiered questions (i.e. you need to circle **both** the number for the answer and the letter for the reason for the answer). Show them a sample (I'll provide one) Give students enough time to consider thoughtfully the questions but I don't think you need a whole period. However, **you probably need more time than the first two interventions** due to the nature of the problems, such as writing out equations. Probably 30 minutes is good. Sort of play it by ear based on whether or not students think they need more time. Give an incentive of a half-point extra credit on the unit exam for each correct answer. Just something minimal, but enough to encourage them to try their best. Of course, do this for wiki class and both control classes as well. I'll observe the classes (treatment group and two control groups) and take the tests when the class is over so I can copy them, grade them that night, and get them back to you the next day so you can use it for exam review.
Within several days of Posttest	Recruit Students	Recruit about 6-8 students for post activity focus group (based on student wiki activity, I'll recommend some students). **Give volunteers parent information sheet, at least a week before focus group, to bring home to parents (it doesn't need to be returned with a signature). Remind them they will get $10 iTunes gift card.**
	Focus Group	Ed will do Focus Group (one group of about 6-8 students each time; about 45-55 minutes) **Students first asked to read and sign Student Assent Form.**
	Teacher Interview	I'll interview you for about 20-30 minutes; you'll also need to sign a consent form.
	Daily Log	Submit your daily log of communications

Appendix O

Sample Help Page (Embedding a Video)

How to Embed a Video

1. Click on Edit on the page you wish to embed the video.

2. In the Edit window, click on Widget.
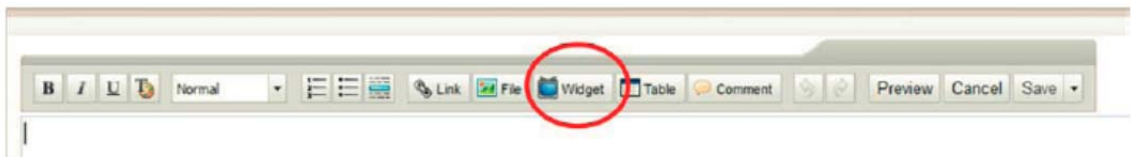
3. In the Widgets window, click on Video.
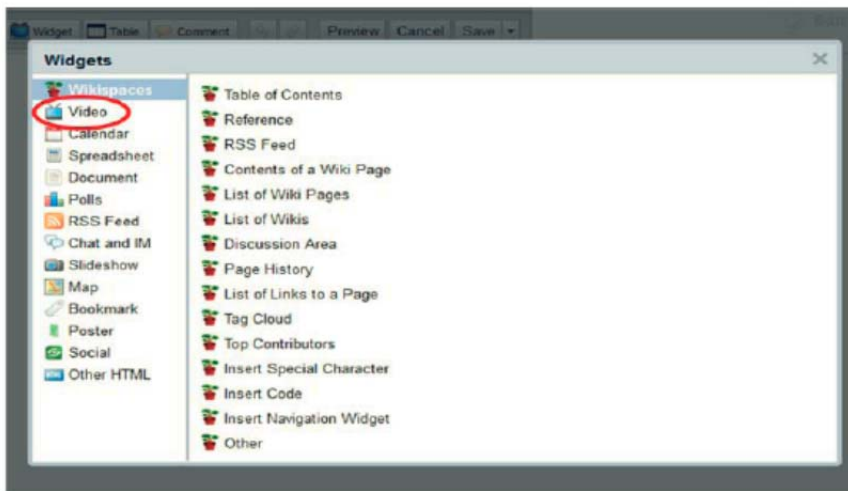
4. For a YouTube video, click on YouTube.
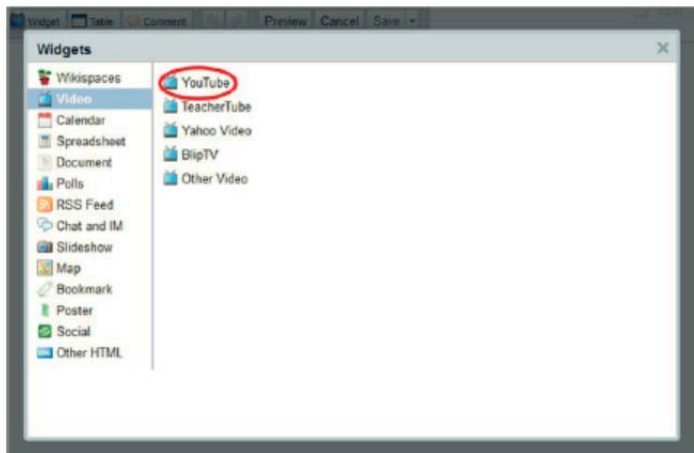
You should now have something that looks like this:
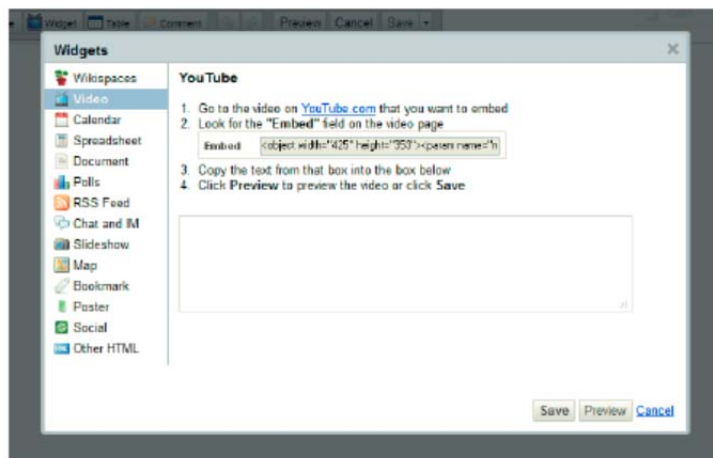
Leave this window for a moment (don't close it).

5. In a new browser window go to the video url, then right-click on the video and select "Copy embed html".

Screen shot blocked to avoid potential copyright violation

Copy video URL
Copy video URL at current time
Pop out
Copy embed html
Report playback issue
Take speed test
Stop download
Show video info
Copy debug info

Settings...
Global Settings...
About Adobe Flash Player 10.3.183.5...
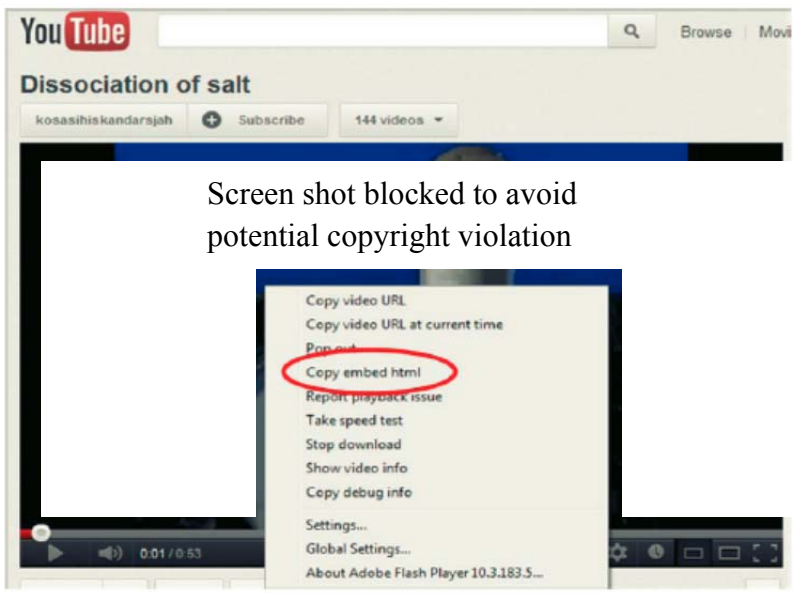
6. Go back to your wiki and paste the html code into the box (usually, you can right-click and select "Paste", or instead of right-click, on a PC use Ctrl+V, and a Mac Command+V). You should now have something that looks like this:
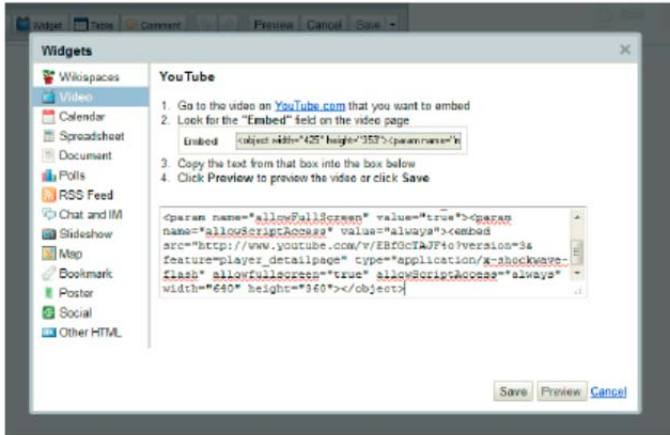
7. Click Save.

8. You should now see something like this:
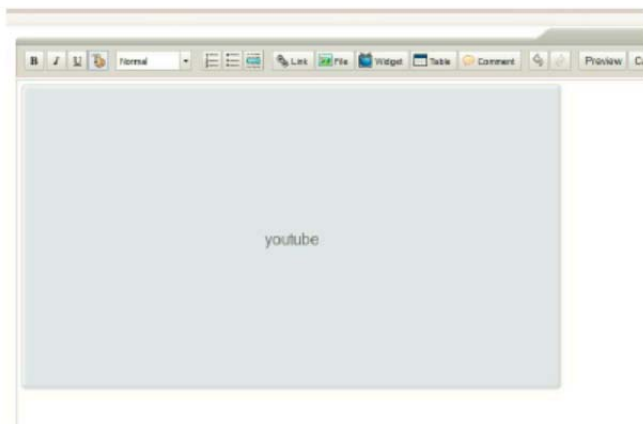
9. Click Save.
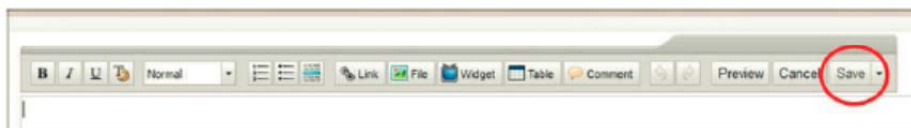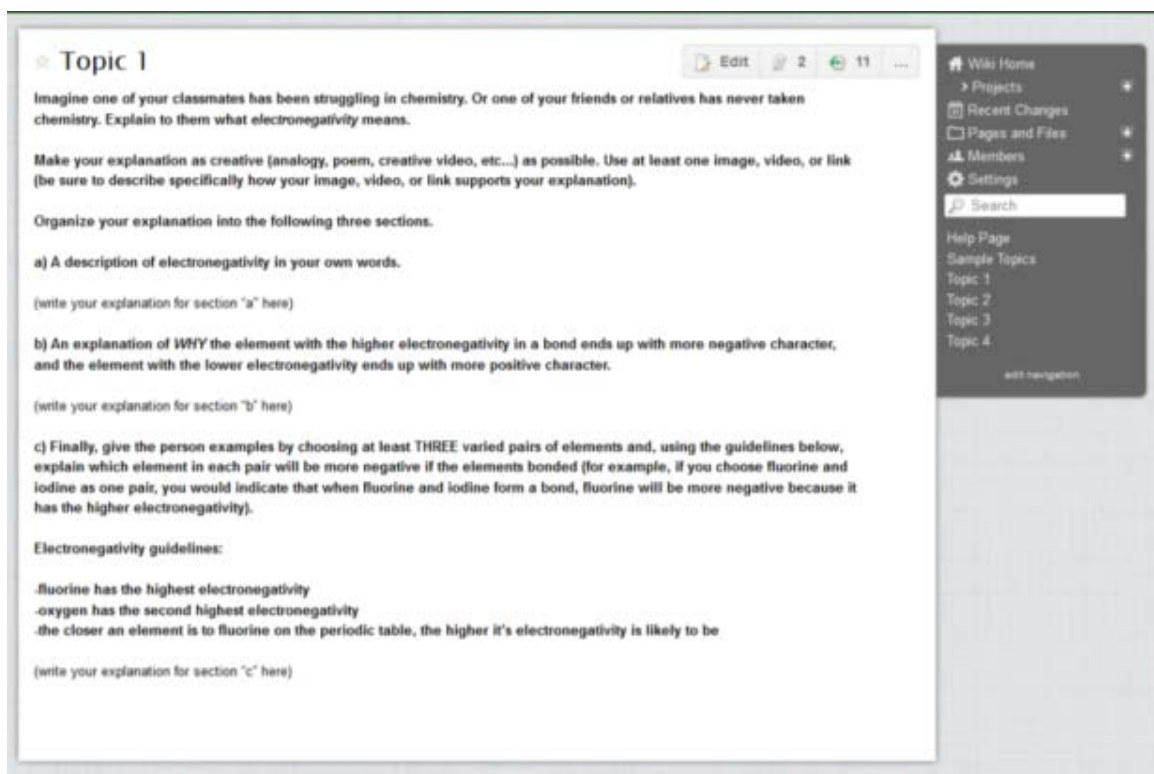
10. Your video should now be embedded on your page and ready for play.

☆ Analysis and Conclusions

Screen shot blocked to avoid potential copyright violation

Appendix P

Bonding Activity Templates

Topic 1

Topic 1

Edit · 2 · 11 · ...

Imagine one of your classmates has been struggling in chemistry. Or one of your friends or relatives has never taken chemistry. Explain to them what electronegativity means.

Make your explanation as creative (analogy, poem, creative video, etc...) as possible. Use at least one image, video, or link (be sure to describe specifically how your image, video, or link supports your explanation).

Organize your explanation into the following three sections.

a) A description of electronegativity in your own words.

(write your explanation for section "a" here)

b) An explanation of *WHY* the element with the higher electronegativity in a bond ends up with more negative character, and the element with the lower electronegativity ends up with more positive character.

(write your explanation for section "b" here)

c) Finally, give the person examples by choosing at least THREE varied pairs of elements and, using the guidelines below, explain which element in each pair will be more negative if the elements bonded (for example, if you choose fluorine and iodine as one pair, you would indicate that when fluorine and iodine form a bond, fluorine will be more negative because it has the higher electronegativity).

Electronegativity guidelines:

-fluorine has the highest electronegativity
-oxygen has the second highest electronegativity
-the closer an element is to fluorine on the periodic table, the higher it's electronegativity is likely to be

(write your explanation for section "c" here)

Wiki Home
> Projects
Recent Changes
Pages and Files
Members
Settings
Search

Help Page
Sample Topics
Topic 1
Topic 2
Topic 3
Topic 4

edit navigation

Topic 2

Topic 2

Edit | 0 | 6 | ...

Three types of chemical bonds are *polar covalent*, *nonpolar covalent*, and *ionic*. The following guidelines can often be used to predict which type of bond will form:

Type of Elements Bonded	Type of Bond
same nonmetal	nonpolar covalent
different nonmetals	polar covalent
metal to nonmetal	ionic

Imagine one of your classmates has been struggling in chemistry. Or one of your friends or relatives has never taken chemistry. Explain these guidelines to them. Make your explanation as creative (analogy, poem, creative video, etc...) as possible.

Organize your explanation into the following three sections:

a) An explanation of how you use a periodic table to identify metals, nonmetals, and metalloids. Include an image or video of a periodic table that makes it easy to distinguish the three types of elements. Note any important exceptions to the general pattern.

(write your explanation for section "a" here)

b) Give the person examples by choosing at least THREE pairs of elements (at least one for each type of bond) and briefly explain, for each pair, why you predicted a particular type of bond would form (for example, if you choose phosphorus and phosphorus, you would indicate the bond between them would be nonpolar covalent because the same nonmetal is bonded together).

(write your explanation for section "b" here)

c) For the polar covalent bond you chose, explain how you determine which end is partially negative and which is partially positive.

(write your explanation for section "c" here)

Topic 3

Topic 3

Edit   0   2   ...

Some students have the misconception that all covalent bonds involve *equal* sharing. Equal sharing of electrons, however, only occurs if the covalent bond is formed between atoms of *identical* electronegativity (this occurs when two atoms of the same element are bonded together, such as S to S or O to O).

In a *creative* way (everyday analogy, poetry, creative video, etc...), explain the following to someone who doesn't have a strong chemistry background.

-no difference in electronegativity results in *equal sharing* of electrons (nonpolar covalent bond)
-a small or medium difference in electronegativity results in *unequal sharing* of electrons (polar covalent bond)
-a large difference in electronegativity results in a complete *transfer* of electrons (ionic bond)

Use at least one image, video, or link to aid your explanation. Make sure to describe specifically how your image, video, or link supports your explanation.

(write your explanation to Topic 3 here)

Topic 4

Topic 4

Edit   0   2   ...

Some students have the misconception that atoms have "needs" or "desires" to form bonds. This is incorrect. Atoms don't "think" about what they need or want. They simply react in certain situations. Specifically, they spontaneously react and form bonds with other atoms if doing so gives them lower energy then they had before. By achieving lower energy, they become *MORE* stable.

In a *creative* way (everyday analogy, poetry, creative video, etc...), provide an explanation for this concept to someone who doesn't have a strong chemistry background.

Use at least one *image, video, or link* to aid your explanation. Make sure to describe specifically how your image, video, or link supports your explanation.

(write your explanation to Topic 4 here)

Appendix Q

Physical Changes Activity Templates

Topic 1

Note: Photo of dry ice chunks blocked to avoid potential copyright violation (see "dry-ice-shipment.jpg," n.d.). Molecular level image of dry ice also not shown to avoid potential copyright infringement; the image had many closely packed CO_2 molecules (see "Carbon-dioxide-crystal-3D-vdW.png," n.d.).

(wiki page continues on the next page)

Change #3:

molecular level
image of $CO_2(s)$
shown here $\longrightarrow$

Change #4:

molecular level
image of $CO_2(s)$
shown here $\longrightarrow$

b) In a creative way, explain to someone with a limited background in chemistry (perhaps a family member, or a friend who has never taken chemistry) that when substances change state into a gas, they do NOT decompose. As part of your explanation, remember to:

-Be creative! Use an analogy, poem, creative video, etc...
-Use at least TWO images, videos, or links to support your explanation (at least one must be one you found on your own and not on the Resources Page). Be sure to describe specifically how each image, video, or link supports your explanation
-Incorporate your answer from section "a" (i.e. briefly explain how your answer from section "a" fits in with your creative explanation for section "b")

Note: Molecular level image of dry ice not shown to avoid potential copyright infringement. The image had many closely packed CO_2 molecules (see "Carbon-dioxide-crystal-3D-vdW.png," n.d.).

Topic 2

Topic 2   Edit   0   63   ...

Some students have the misconception that conservation of matter does not occur in physical changes. This is incorrect. Physical changes *always* involve conservation of matter (so do chemical changes, by the way). This means both atoms and mass are conserved. That is, there are the same number and type of atoms before and after the physical change, and there is the same total mass before and after the physical change.

Perhaps you have heard of liquid nitrogen. It is very cold (-320 °F, -196 °C) and boils at room temperature and pressure. Take a look:

embedded video of liquid nitrogen boiling in a beaker was here

Imagine atoms of nitrogen and molecules of nitrogen could be represented like this:

nitrogen atom (N):

nitrogen molecule (N₂):

Now, imagine we could actually see ALL the nitrogen molecules and that we used a closed container so the gas wouldn't escape (of course, there are many, many more molecules in a typical container than what you see here, but for now just imagine there are only these):

liquid nitrogen   gaseous nitrogen

a) Does the change from liquid nitrogen to gaseous nitrogen involve conservation of matter? Explain your rationale, making sure to refer to the diagram above in your explanation.
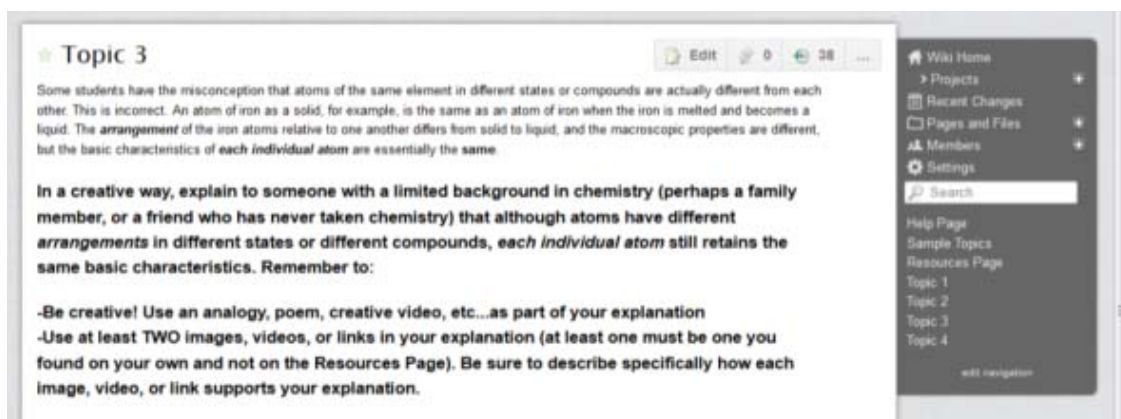
b) In a creative way, explain to someone with a limited background in chemistry (perhaps a family member, or a friend who has never taken chemistry) that both *ATOMS and MASS are conserved during physical changes*. Remember to:

-Be creative by using an analogy, poem, creative video, etc....as part of your explanation.
-Use at least TWO images, videos, or links to support your explanation (at least one must be one you found on your own and not on the Resources Page). Make sure to describe specifically how your images, videos, or links support your explanation.
-Incorporate your answer from section "a" (i.e. briefly explain how your answer from section "a" fits in with your creative explanation for section "b")

Help   About   Blog   Pricing   Privacy   Terms   Support   Upgrade

Wiki Home
Projects
Recent Changes
Pages and Files
Members
Settings
Search

Help Page
Sample Topics
Resources Page
Topic 1
Topic 2
Topic 3
Topic 4

edit navigation

Note: Screen shot of embedded video of liquid nitrogen boiling in a beaker not shown to avoid potential copyright violation (see "Liquid nitrogen boiling in a beaker," 2008).

Topic 3

Topic 3

Some students have the misconception that atoms of the same element in different states or compounds are actually different from each other. This is incorrect. An atom of iron as a solid, for example, is the same as an atom of iron when the iron is melted and becomes a liquid. The *arrangement* of the iron atoms relative to one another differs from solid to liquid, and the macroscopic properties are different, but the basic characteristics of *each individual atom* are essentially the *same*.

In a creative way, explain to someone with a limited background in chemistry (perhaps a family member, or a friend who has never taken chemistry) that although atoms have different *arrangements* in different states or different compounds, *each individual atom* still retains the same basic characteristics. Remember to:

-Be creative! Use an analogy, poem, creative video, etc...as part of your explanation
-Use at least TWO images, videos, or links in your explanation (at least one must be one you found on your own and not on the Resources Page). Be sure to describe specifically how each image, video, or link supports your explanation.

Topic 4

Topic 4   Edit   0   60   ...

Consider the following seven containers. Each represents either an *element*, a *compound*, or a *mixture*.

1

2

3

4

5

6

7

Key:

helium atoms: chlorine atoms: hydrogen atoms: oxygen atoms: sulfur atoms:

a) Identify the contents of each container as an element, compound, or mixture. Briefly explain your choices.

b) In a creative way, explain to someone with a limited background in chemistry (perhaps a family member, or a friend who has never taken chemistry) the molecular level differences between an ELEMENT, COMPOUND, and MIXTURE (i.e. what each would look like and how would they differ if you could actually see the atoms and molecules). As part of your explanation, remember to:

-Be creative! Use an analogy, poem, creative video, etc...
-Use at least TWO images, videos, or links as part of your explanation (at least one must be one you found on your own and not on the Resources Page). Be sure to explain how your image, video, or link supports your explanation.
-Incorporate your answer from section "a" (i.e. briefly explain how your answer from section "a" fits in with your creative explanation for section "b")

Appendix R

Chemical Changes Activity Templates

Topic 1

Topic 1

Edit | 0 | 16 | ...
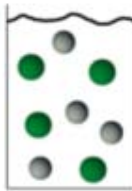
Some students have misconceptions about *aqueous* (i.e. dissolved in water) ionic compounds. They think aqueous ionic substances exist as molecular pairs of ions. They don't realize they exist as *independent* ions in solution.

Imagine a sodium ion, Na^+, and a bromide ion, Br^-, could be represented as follows:

Na^+ = ⚪ Br^- = 🟢

a) Which of the following diagrams best represents aqueous sodium bromide, NaBr(aq)? Briefly explain why you chose the one you did.

#1)   #2)   #3)

b) In a creative way (everyday analogy, poetry, creative video, etc...), explain to someone who doesn't have a strong background in chemistry that aqueous ionic compounds exist as independent ions in solution

Use at least one image, video, or link to aid your explanation. Make sure to describe specifically how your image, video, or link supports your explanation.

Topic 2

Topic 3

Topic 4

Topic 4

Edit ✎ 0 ⟲ 10 ...

Although **spectator ions** appear in the molecular equation for a precipitation reaction, they do not participate in the reaction. They just watch. That's why they're called spectators! They are *independent* ions in solution before **and** after the reaction.

Imagine a sodium ion (Na^+), bromide ion (Br^-), silver ion (Ag^+), and nitrate ion (NO_3^-) could be represented as follows:

Na^+ = ⚪ Br^- = 🟢 Ag^+ = 🔴 NO_3^- = 🔵

a) Now consider a precipitation reaction that can be represented by the following diagram. Identify the spectator ions in the reaction and briefly explain your choice *by referring to what is happening in the diagram.*

b) Write a balanced molecular equation, complete ionic equation, and net ionic equation for the reaction represented in the above diagram. (If you don't know how to create subscripts or superscripts on Wikispaces, click here for help)

molecular equation:

complete ionic equation:

net ionic equation:

c) In a creative way (everyday analogy, poetry, creative video, etc...), explain to someone who doesn't have a strong chemistry background that spectator ions exist as independent ions before *and* after a precipitation reaction

Use at least one image, video, or link to aid your explanation. Make sure to describe specifically how your image, video, or link supports your explanation.

Appendix S

Rubric – Bonding Activity

Bonding Wiki Activity   **Grading Rubric**

Name _____   Date_____   Period: _____

Complete the student score before turning in this grading rubric (or docked 1 point)

Criteria	Points Possible	Student Score	Teacher Score
Initial Face-to-Face Group Discussion ❑ Each member assigned an initial topic to begin working on (2) ❑ Group members discuss topics and creative ideas in small group and whole class discussion (2)	4		
Initial Contributions to Wiki ❑ By the end of _____ every group member needs to have made at least one contribution to their initial wiki topic (4)	4		
Midpoint Contributions to Wiki (Topics 1 and 2) ❑ By the end of _____ each group member assigned to Topic 1 or 2 needs to have completed a first draft ❑ Explanations and examples are clear and accurate (7) ❑ Good faith attempt at creativity (2) ❑ Image, video, or link included (3) (for Topic 2, the link needs to be a periodic table that aids the explanation)	12		
or Midpoint Contributions to Wiki (Topics 3 and 4) ❑ By the end of _____ each group member assigned to Topic 3 or 4 needs to have completed a first draft ❑ Explanation is clear and accurate (5) ❑ Good faith attempt at creativity (4) ❑ Image, video, or link included (3)	12		
Midpoint Face-to-Face Group Discussion ❑ Group members discuss each topic and strategies for improvement (4)	4		

Criteria	Points Possible	Student Score	Teacher Score
Final Contributions to Wiki (between Midpoint and Final due Date) ❑ Every group member needs to make at least one *significant* contribution to the wiki for **each** topic that was not initially assigned to them (4 pts for each) ❑ This can be done by adding significant text, image, video, or link (with explanation) **OR** by adding an additional example (with explanation)	12		
Topic 1 Final Criteria ❑ Chemistry concepts are explained clearly and accurately (5) ❑ Included description of electronegativity in your own words (2) ❑ Included explanation of what causes the element with the higher electronegativity to have more negative character (2) ❑ At least three examples provided and explained (3) ❑ At least one image, video, link or other resource included and explained (2) ❑ Good faith attempt at creativity (2)	16		
Topic 2 Final Criteria ❑ Chemistry concepts are explained clearly and accurately (5) ❑ Included explanation of how to use periodic table to identify metals, nonmetals, and metalloids (including important exceptions) (2) ❑ At least three examples provided and explained (3) ❑ Explained partial negative and partial positive end of polar covalent bond (2) ❑ Link or image included that makes it easy to distinguish between metals, nonmetals, and metalloids on the periodic table (2) ❑ Good faith attempt at creativity (2)	16		
Topic 3 Final Criteria (Creativity very important!) ❑ Chemistry concepts are explained clearly and accurately (4) ❑ Included explanation of large, small/medium, and no difference in electronegativity (3) ❑ At least one image, video, link or other resource included and explained (3) ❑ Good faith attempt at creativity (6)	16		
Topic 4 Final Criteria (Creativity very important!) ❑ Chemistry concepts are explained clearly and accurately (4) ❑ At least one image, video, link or other resource included and explained (3) ❑ Good faith attempt at creativity (9)	16		
Extra Credit ❑ Develop a multimedia presentation to explain one of the chemistry topics and link to it from your wiki (examples you might consider: Animoto, Go Animate, Prezi…or choose one of you own) (8)	8		

❑ This extra credit not possible if assignment otherwise incomplete			
Extra Credit ❑ Use wiki discussion forum to communicate to group members and explain in detail why you made particular changes (3) ❑ Use wiki discussion forum to reply to postings (not just those in your initial topic) to indicate you read them (2)	5		
TOTAL	100		

Appendix T

Rubric – Physical Changes Activity

Physical Changes Wiki Activity   **Grading Rubric**

Name _____   Date_____   Period: _____

Complete the student score before turning in this grading rubric (or docked 1 point)

Criteria	Points Possible	Student Score	Teacher Score
Initial Face-to-Face Group Discussion ❑ Each member assigned an initial topic to begin working on (2) ❑ Group members discuss topics and creative ideas in small group and whole class discussion (2)	4		
Initial Contributions to Wiki ❑ By the end of _____ every group member needs to have made at least one contribution to their initial wiki topic (4)	4		
Midpoint Contributions to Wiki ❑ By the end of _____ each group member needs to have completed a first draft of their topic ❑ Explanations and examples are clear and accurate (5) ❑ All aspects of the topic answered and explained (2) ❑ Good faith attempt at creativity (2) ❑ Two images, videos, or links included and explained (3) (at least one found on your own and not on Resources Page)	12		
Midpoint Face-to-Face Group Discussion ❑ Group members discuss each topic and strategies for improvement (4)	4		

Criteria	Points Possible	Student Score	Teacher Score
Final Contributions to Wiki (between Midpoint and Final due Date) ❑ Every group member needs to make at least one *significant* contribution to the wiki for **each** topic that was not initially assigned to them (4 pts for each) ❑ This can be done by adding significant text, image, video, or link (with explanation) **OR** by adding an additional example (with explanation)	12		

Criteria	Points Possible	Student Score	Teacher Score

Topic 1 Final Criteria
    Section "a":
❑ Identified and correctly explained which change accurately shows sublimation (3)
    Section "b":
❑ Good faith attempt at creativity (4)
❑ Incorporated answer and explanation to section "a" (1)
❑ At least TWO images, videos, or links included and explained (at least one of which was not found on the Resources Page) (4)
❑ Chemistry concepts explained clearly and accurately (4)
	16		

Topic 2 Final Criteria
    Section "a":
❑ Correctly explained if the change involved conservation of matter and referred to the diagram (3)
    Section "b":
❑ Good faith attempt at creativity (4)
❑ Incorporated answer and explanation to section "a" (1)
❑ At least TWO images, videos, or links included and explained (at least one of which was not found on the Resources Page) (4)
❑ Chemistry concepts explained clearly and accurately (4)
	16		

Topic 3 Final Criteria (Creativity especially important for this one!) ❑ Chemistry concepts explained clearly and accurately (5) ❑ At least TWO images, videos, or links included and explained (at least one of which was not found on the Resources Page) (4) ❑ Good faith attempt at creativity (7)	16		

Topic 4 Final Criteria
    Section "a":
❑ Identified and correctly explained the contents of each container (3)
    Section "b":
❑ Good faith attempt at creativity (4)
❑ Incorporated answer and explanation to section "a" (1)
❑ At least TWO images, videos, or links included and explained (at least one of which was not found on the Resources Page) (4)
❑ Chemistry concepts explained clearly and accurately (4)
	16		

Extra Credit ❑ Develop a multimedia presentation to explain one of the chemistry topics and link to it from your wiki (examples you might consider: Animoto, Go Animate, Prezi…or choose one of you own) (8) ❑ This extra credit not possible if assignment otherwise incomplete	8		
Extra Credit ❑ Use wiki discussion forum to communicate to group members and explain in detail why you made particular			

changes (3) ❑ Use wiki discussion forum to reply to postings (not just those in your initial topic) to indicate you read them (2)	5		
TOTAL	100		

Appendix U

Rubric – Chemical Changes Activity

Chemical Changes Wiki Activity   **Grading Rubric**

Name _____   Date_____   Period: _____

Complete the student score before turning in this grading rubric (or docked 1 point)

Criteria	Points Possible	Student Score	Teacher Score
Initial Face-to-Face Group Discussion ❏ Each member assigned an initial topic to begin working on (2) ❏ Group members discuss topics and creative ideas in small group and whole class discussion (2)	4		
Initial Contributions to Wiki ❏ By the end of _____ every group member needs to have made at least one contribution to their initial wiki topic (4)	4		
Midpoint Contributions to Wiki ❏ By the end of _____ each group member needs to have completed a first draft of their topic ❏ Explanations and answers are clear and accurate (5) ❏ All aspects of the topic answered and explained (2) ❏ Good faith attempt at creativity (2) ❏ At least one image, video, or link included and explained (3)	12		
Midpoint Face-to-Face Group Discussion ❏ Group members discuss each topic and strategies for improvement (4)	4		

Criteria	Points Possible	Student Score	Teacher Score
Final Contributions to Wiki (between Midpoint and Final due Date) ❏ Every group member needs to make at least one *significant* contribution to the wiki for **each** topic that was not initially assigned to them (4 pts for each) ❏ This can be done by adding significant text, image, video, or link (with explanation) **OR** by adding an additional example (with explanation)	12		

Criteria	Points Possible	Student Score	Teacher Score

Topic 1 Final Criteria
 	
   Section "a":
❑ Identified and correctly explained which diagram best represents aqueous sodium bromide (4)
   Section "b":
❑ Good faith attempt at creativity (4)
❑ At least one image, video, or link included and explained (4)
❑ Chemistry concepts explained clearly and accurately (4)
	16		

Topic 2 Final Criteria
 	
   Section "a":
❑ Identified and correctly explained which diagram best represents a precipitate of barium sulfate (4)
   Section "b":
❑ Good faith attempt at creativity (4)
❑ At least one image, video, or link included and explained (4)
❑ Chemistry concepts explained clearly and accurately (4)
	16		

Topic 3 Final Criteria (Creativity especially important for this one!) ❑ Chemistry concepts explained clearly and accurately (5) ❑ At least one image, video, or link included and explained (4) ❑ Good faith attempt at creativity (7)	16		

Topic 4 Final Criteria
 	
   Section "a":
❑ Correctly identified the spectator ions and explained accurately by referring to the diagram (2)
Section "b":
❑ Accurately wrote balanced molecular equation, complete ionic equation, and net ionic equation (4)
   Section "c":
❑ Good faith attempt at creativity (4)
❑ At least one image, video, or link included and explained (3)
❑ Chemistry concepts explained clearly and accurately (3)
	16		

Extra Credit ❑ Develop a multimedia presentation to explain one of the chemistry topics and link to it from your wiki (examples you might consider: Animoto, Go	8		

Animate, Prezi…or choose one of you own) (8) ❑ This extra credit not possible if assignment otherwise incomplete			
Extra Credit ❑ Use wiki discussion forum to communicate to group members and explain in detail why you made particular changes (3) ❑ Use wiki discussion forum to reply to postings (not just those in your initial topic) to indicate you read them (2)	5		
TOTAL	100		

Appendix V

Sample Topics With Idealized Answers

☆ **Sample Topics**   ⬜ Edit 0 ⬅ 2 ...

Sample Topic 1: Some students have the misconception that new elements can easily be formed under ordinary conditions. Explain why the misconception is incorrect.

Sample Explanation: Let's say about 100 people are out dancing one night at a dance club. As the night goes on, lots of different combinations of men and women dance together doing the cha-cha, rumba, and others. Everyone is having a good time.

But now imagine that one of the dancers you dance with just happens to be a terrible dancer! They are so bad you wish you could just snap your fingers and change them into someone else. They are like the dancers in this video:

embedded video of really bad dancing was here

But, of course, you can't just snap your fingers and change someone into someone else. That's impossible! But what you can do is wait until the next dance and then get a new partner. That's relatively easy.

In the same way, it's fairly easy to use existing elements and combine them in different ways to form new compounds.

For example, when natural gas burns, methane (CH_4) reacts with oxygen (O_2) to produce carbon dioxide (CO_2) and water (H_2O). The chemical equation is:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Note: Screen shot of embedded video of really bad dancing not shown to avoid potential copyright violation (see "Really bad dancing," 2006). Clip art is from Microsoft Office.

The three elements that existed before the reaction (C, H, and O) are the **same elements** that are present after the reaction. They are just combined differently. Carbon was paired with hydrogen before the reaction in CH_4, and it's now paired with oxygen after the reaction in CO_2. But what's important to realize is that no new elements have formed. It's just different combinations of C, H, and O. What hasn't happened is changing one element, like carbon, into another known element (helium, nitrogen, etc...) or a completely new, previously unknown element.

It is not impossible for scientists to produce new elements, but it is VERY difficult! New elements are only produced under extraordinary conditions created in specially designed laboratories. For example, giant particle accelerators are needed to smash protons or whole atoms into other atoms to create new elements. This does not happen often and the new elements that are formed are very unstable and have no practical use.

Sample Topic 1 Score (if it was graded using the rubric from the first activity you did):
9 points for a clear and accurate chemistry explanation (max 9 points)
4 points for creativity (max 4 points)
2 points for including an image, video, link or other resource (max 2 points)
Total Score for Sample Topic 1: 15/15

Sample Topic 2: Some students have the misconception that the physical properties of a substance (color, density, hardness, etc...) are also properties of the individual atoms that make up that substance. Explain why the misconception is incorrect.

Sample Explanation: The physical properties of a substance (color, density, hardness, melting point, boiling point, etc...) are not the same as the properties of the individual atoms that make up that substance. For example, let's say you had some carbon in the form of graphite (graphite is what is found in your pencil). The graphite has a grayish color and is very brittle (it's easy to crush it into little pieces). But that does not mean that the individual carbon atoms that make up graphite are also gray and brittle. In fact, individual carbon atoms are the same no matter what the macroscopic properties of the substance is.

For example, diamond is also a form of pure carbon. Diamond and graphite have very different physical properties (for one, diamond is extremely hard, but graphite is not). But the individual atoms that make up both diamond and graphite are identical. What makes diamond and graphite different from each other is how the atoms are connected to each other, not the nature of the individual atoms themselves.

The following YouTube video explains more about some of the differences between diamond and graphite (such as diamond is lustrous and graphite is dull; and diamond is a non-conductor and graphite a conductor). But it's important to remember that in spite of these differences, each individual atom in diamond has exactly the same characteristics as each individual atom in graphite.

(continued on next page)

embedded video describing
the structure of diamond
and graphite was here

Sample Topic 2 Score (if it was graded using the rubric from the first activity you did):
9 points for a clear and accurate chemistry explanation (max 9 points)
1 point for creativity; less than the maximum because there was limited attempt to make it creative (max 4 points)
2 points for including an image, video, link or other resource (max 2 points)
Total Score for Sample Topic 2: 12/15

Sample Topic 3: Review the animations and videos from the following links. They all describe the Rutherford Experiment.

http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/ruther14.swf
http://www.youtube.com/watch?v=_uEFKG122dA
http://www.youtube.com/watch?v=fFY4R5mkMY8

Explain in detail how the animations demonstrate the following three concepts:

1) Most of the volume outside the nucleus is empty space
2) Most of the mass of an atom resides in the nucleus
3) The nucleus is very small and positively charged

Sample Explanation: First, consider that most of the alpha particles went directly through the gold foil, without being deflected and without bouncing back. Rutherford concluded from this that most of the volume of the atom must be empty space.

This would be similar to if you were playing with a toddler brother or sister in your bedroom. And you were sitting on the floor on one side of the bed and the toddler was sitting on the floor on the other side. If you rolled a ball under the bed, back and forth to each other, and the ball always made it to the other side undeflected, you might assume that there was only empty space under the bed (i.e. no shoes, toys, clothes).

Note: Screen shot of embedded video describing the structure of diamond and graphite not shown to avoid potential copyright violation (see "Structure of diamond and graphite," 2010)

(continued on the next page)

In Rutherford's experiment, every once in a while, the alpha particles would hit something and bounce back or get deflected. This suggested to him that there must be a very small region that was fairly dense (lots of mass and little volume). He suggested this small region (which he called the nucleus) was very dense because the alpha particles themselves are very dense. And the nucleus must be dense enough to resist the dense alpha particle.

This would be like rolling the ball under the bed, but every now and then it would bounce back, or be deflected to the side. In this case, you would assume that it had hit something dense under the bed (like a shoe or a box), but not something flimsy like a piece of tissue paper.

It was mentioned in the animation (the first link) that the nucleus of the atom was so small that it was about 20,000 times smaller than the volume of the entire atom. This would mean that if the size of the atom were about the size of a large soccer stadium, the size of the nucleus would be only about the size of a marble at midfield!

Image comparing the size of a marble to the size of a soccer stadium shown here

the size of the nucleus would only be about as large as a marble.

source: http://physicaplus.org.il/zope/home/1223030912/god_particle_en/?skin=print

Therefore the images of the nucleus and the atom in the three animations above are not drawn to scale (the nucleus is MUCH smaller relative to the overall size of the atom than is shown in the animations). Atoms really are a LOT of empty space!

Rutherford also suggested that the nucleus would be positively charged because alpha particles themselves were positive, and since like charges repel, this would contribute to the alpha particles bouncing back or being deflected.

Sample Topic 3 Score (if it was graded using the rubric from the first activity you did):
9 points for a clear and accurate chemistry explanation (max 9 points)
4 points for creativity (max 4 points)
2 points for including an image, video, link or other resource (max 2 points)
Total Score for Sample Topic 3: 15/15

Note: Image comparing the size of a marble to the size of a soccer stadium not shown to avoid potential copyright violation (see "Image002.jpg," n.d.).

Appendix W

Sample Control Group Problems

Bonding

The problems below are from Zumdahl, Zumdahl, and DeCoste (2007).

1. For each of the following pairs of bonds, choose the bond that is more polar:

a. H-P, H-C
b. O-F, O-I
c. N-O, S-O
d. N-H, Si-H

(p. 404)

2. What is meant by the term chemical bond? What subatomic particles are most important in bonds? (p. 406)

3. How are ionic bonds and covalent bonds different? (p. 406)

4. How do electronegativity values help in determining the polarity of a bond? (p. 406)

5. What do chemists mean by the term electronegativity? What does its electronegativity tell us about the atom? (p. 435)

6. What does it mean to say that a bond is polar? What are the conditions that give rise to a bond's being polar? (p. 435)

7. For each of the following sets of elements, identify the element expected to be most electronegative and that expected to be least electronegative. (p. 435)

8. On the basis of the electronegativity values given in figure 12.4, indicate whether each of the following bonds would be expected to be ionic, covalent, or polar covalent.

a. S-S
b. S-O
c. S-H
d. S-K

(p. 435)

Physical Changes

1. Students were asked to read several textbook pages (Zumdahl et al., 2007), and take notes on what they read. Content from these pages included:

-A description of the general differences between solids, liquids, and gases. For example, gases were described as low density, highly compressible, and able to fill a container. Solids, on the other hand, were described as high density, slightly compressible, and rigid. Liquids were described as somewhat between a gas and a liquid. (p. 488)

-A description of the molecular motion of water as temperature increases and how temperature only increases after a phase change is complete (i.e. if boiling, the temperature would only increase after all the liquid water had changed into a gas). (p. 492)

-When water reaches 100 $^{\circ}$C bubbles develop in the interior of the liquid. (The text does not explicitly state these bubbles are water vapor). (p. 492)

-A molecular level image of water molecules boiling and becoming a gas. (p. 493)

2. Students also were provided with a worksheet (original source unknown). Some questions dealt with a phase diagram.

"With each passing minute, _____ is added to the substance. This causes the molecules of the substance to _____more rapidly which we detect by a _____ increase in the substance."

 "During the time from point D to point E, the liquid is _____. By point E, the substance is completely in the _____phase. Material in this phase has _____ volume and _____ shape. The energy put to the substance between minutes 13 and 18 converted the substance from a _____ to a _____ state. Beyond point E, the substance is still in the _____ phase, but the molecules are moving _____ as indicated by increasing temperature. "

3. Make up the structure of the molecule and draw it to the right. Now draw a particle diagram of the substance in a solid, liquid, and gaseous state on the back of this worksheet. Be sure to label your diagrams. (this question was also on the worksheet; original source unknown)

Chemical Changes

The problems below are from Zumdahl, Zumdahl, and DeCoste (2007).

1. On the basis of the general solubility rules given in the table, write a balanced molecular equation for the precipitation reactions that take place when the following aqueous solutions are mixed. Underline the formula of the precipitate (solid) that forms. If no precipitation reaction is likely for the reaction given, so indicate.

a. silver nitrate and hydrochloric acd
b. copper (II) sulfate and ammonium carbonate
c. iron (II) sulfate and potassium carbonate

(p. 276)

2. For each of the following unbalanced molecular equations, write the corresponding balanced net ionic equation for the reaction.

a. $HCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + HNO_3(aq)$

b. $Pb(NO_3)_2(aq) + BaCl_2(aq) \rightarrow PbCl_2(s) + Ba(NO_3)_2(aq)$

(p. 276)

3. When an aqueous solution of silver nitrate is mixed with an aqueous solution of potassium chloride, which are the spectator ions?

a. nitrate ions and chloride ions
b. nitrate ions and potassium ions
c. silver ions and chloride ions
d. silver ions and potassium ions

(p. 277)

This control group also worked on some problems not directly related to the wiki problems, such as determining empirical formulas from percent composition.

Appendix X

Focus Group Protocol

The follow questions are designed to guide the interviews. As this is a semi-structured protocol, questions are open-ended and intended to be followed by more probing questions based on respondents' answers to initial questions.

1. Let's start by getting some general thoughts. What were some of your overall impressions of the activity?

2. The following two questions deal with how *students* supported one another in their learning (later, will ask about how *teacher* supported students).

2a. Were there situations in which support from another student was particularly helpful? If so, please describe.

    [Potential probes:
    -Did it help with learning content, how to use wiki, other?
    -What about help with English language skills?
    -Was the communication face-to-face, wiki discussion board, other?]

2b. Were there instances in which support from another student was not as helpful? If so, please describe. Don't think of it as you are criticizing them, but rather that you just didn't understand what they were trying to say, or what they wrote, in that particular instance.

    [Potential probes:
    -Did it relate to content, or how to use the wiki, or other?
    -Was the communication face-to-face, wiki discussion board, other?]

3. The next two questions deal with how the *teacher* supported your learning.

3a. Were there situations in which support from the teacher was particularly helpful? If so, please describe.

    [Potential probes:
    -Did it help with learning content, how to use wiki, other?
    -Was the communication face-to-face, wiki discussion board, other?]

3b. Were there instances in which support from the teacher was not as helpful? If so, please describe. Don't think of it as you are criticizing them, but rather that you just didn't understand what they were trying to say, or what they wrote, in that particular instance.

[Potential probes:
-Did it relate to content, or how to use the wiki, or other?
-Was the communication face-to-face, wiki discussion board, other?]

4. Overall, do you think this type of activity is better suited for support from other students or support from the teacher, or some of both? Please explain.

5. Can you identify any other situations in which a fellow student or the teacher offered helpful advice, either face-to-face or in writing?

6. Compare the various communication options that are available for this activity (face-to-face, discussion board, other). Is there one in particular that you find most effective for an activity like this? Why?

   [Potential Probe:
   -Is there one that you find least effective and why?]

7. One of the requirements of this activity was to be creative in a way that would help someone who didn't know much chemistry to understand the topic. Describe what you first thought of when considering how to be creative and how you eventually decided on what to do.

8. At the start of the activity, you were asked to divide up tasks, so that each group member would take one aspect of the requirements and be the first to write about it. Do you think this was a good strategy for getting started? Explain.

   [Potential Probes:
   -Did you feel you learned all of the content equally well, including the topics that were not initially assigned to you?]

9. How did you feel about editing someone else's work?

   [Potential Probe:
   -Did you ever feel like you should ask them about it first?
   -Before the activity, the teacher mentioned students sometimes feel awkward editing another student's work, but that it was important to overcome this. Did that help at all?]

10. Is there anything else we haven't talked about that you would like to share about your experience with this activity?

Appendix Y

Teacher Interview Protocol

The follow questions are designed to guide the interviews. As this is a semi-structured interview, questions are open-ended and intended to be followed by more probing questions based on the respondent's answers to initial questions.

1. Let's start by getting some general thoughts. What were some of your overall impressions of the activity?

2. The following two questions deal with how you supported student learning by communicating with students.

2a. Describe instances, if any, in which you felt you effectively supported students learning, such as by offering an explanation about content.

   [Potential Probes:
   -wiki discussion forum? Face-to-face? Other?
   -Technical issues instead of content?
   -other ways of effective support?]

2b. Describe any instances, if any, in which you felt you tried to support students by offering an explanation, but the student didn't seem to understand, or you felt it was ineffective.

   [Potential Probes:
   -wiki discussion forum? Face-to-face? Other?
   -Technical issues instead of content?
   -other examples of ineffective support?]

3. The following two questions deal with how students supported each other in their learning.

3a. Describe instances, if any, in which you observed students effectively helping one another learn the content.

   [Potential Probes:
   -wiki discussion forum? Face-to-face? Other?
   -Technical issues instead of content?]

3b. Describe any instances, if any, in which students tried to help one another learn the content but you felt it was ineffective.

[Potential Probes:
-wiki discussion forum? Face-to-face? Other?
-Technical issues instead of content?]

4. Overall, do you think this type of activity is better suited for students supporting one another or for the teacher supporting students, or some of both? Please explain.

5. Can you identify any other situations in which a fellow student or the teacher offered helpful advice, either face-to-face or in writing?

6. Compare the various communication options that are available for this activity (face-to-face, discussion board, other). Is there one in particular that you find most effective for an activity like this? Why?

    [Potential Probe:
    -Is there one that you find least effective and why?]

7. Is there anything else we haven't talked about that you would like to share about your experience with this activity?

Appendix Z

Internet Access Survey

Recently, you participated in a wiki activity that is part of a research study led by Mr. O'Sullivan, a doctoral student at Marquette University. To help him understand the results, this survey contains four brief questions that should take no more than five minutes of your time. Getting your input is vital and is greatly appreciated. However, your responses are completely voluntary. If you do not wish to participate, just hand in the survey sheet without answering. If you do choose to participate, your responses will be confidential. In fact, please do not put your name on the paper. All responses will be compiled together and analyzed as a group.

If you have any questions about the study, you can ask Mr. O'Sullivan or (name redacted). We will try to explain everything that is being asked and why. Please ask us about anything you want to know. Also, if you need clarification about one of the questions, please don't hesitate to ask.

----

1) Do you have internet access at home? (circle your choice)

   Yes   No

2) If you answered "No" to question #1, skip to question #3.

If you answered "Yes" to question #1, is there anything that inhibits your ability to **fully** utilize your home internet access (i.e. very slow connection, another family member is often using the only computer in the house, etc…)? Briefly explain.

3) During the activity, how often, if at all, did you go to places outside of school and home to use the internet (i.e. McDonald's, Starbucks, public library, etc…)? (circle your choice)

   Twice or more   Once   Never

4) Do you have any other comments about your ability to access the internet during the wiki activity?

Appendix AA

List of Acronyms

CBAT	Chemical Bonding Achievement Test
CBCT	Chemical Bonding Concept Text
CC	Chemical Changes
CC-2	Chemical Changes Group 2
CC-4	Chemical Changes Group 4
CCT	Conceptual Change Text
FIFA	Fédération Internationale de Football Association
MS	Metacognitive Scaffolding
MS-CK	Metacognitive Scaffolding – Content Knowledge
MS-GGK	Metacognitive Scaffolding – General Goals Knowledge
MS-MCK	Metacognitive Scaffolding – Making Connections Knowledge
MS-SK	Metacognitive Scaffolding – Strategy Knowledge
NI	Normal Instruction
PC	Physical Changes
PC-1	Physical Changes Group 1
PC-2	Physical Changes Group 2
STEM	Science, Technology, Engineering, and Mathematics
ZPD	Zone of Proximal Development

Appendix BB

Wiki Activity Timetables

Bonding (25 days in October/November; 16 days if you don't count the blue shaded dates)

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					Intro Day	
		Initial Contribution				
	First Post	Midpoint			Second Post	
	Deadline	Posttest				

blue shaded dates = very limited wiki activity; only one student made edits during this time (active participation delayed until topics were more fully covered in class)

Physical Changes (16 days in November/December)

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	Intro Day (SP)			*Thanksgiving*	Initial Contribution	
			First Post / Midpoint			Second Post
	Original Deadline	Revised Deadline	Posttest			

SP = short period

Chemical Changes (13 days in February)

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			Intro Day	Initial Contribution		
			First Post / Midpoint			Second Post
	Deadline	Posttest				