THE USE OF HIGHER ORDER COGNITIVE STRATEGIES TO IMPROVE STUDENT UNDERSTANDING OF HIGH SCHOOL CHEMISTRY CONCEPTS

by

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ABSTRACT

In this project, Higher Order Cognitive Strategies (HOCS) were investigated to determine if they helped students' understanding of high school chemistry concepts. Prior to the project, I found my students to be able to take basic chemistry information and work with it at the time, but find limitations in their abilities to transfer the concepts that were learned to other paths or to use them in other situations in the class after they were taught. I investigated their ability to understand chemistry concepts better using HOCS, their ability to answer HOCS questions, their retention of chemistry concepts in long-term memory as a result of HOCS, their attitudes about learning chemistry through HOCS, and attitudes regarding planning and implementation of HOCS units. The results were very indecisive from this study, however, there was support that HOCS may lead to better understanding of chemistry concepts overall. Additionally, it was determined that students did not think they liked learning via HOCS, but that surveys that compared nontreatment and treatment units supported their preference to HOCS.

INTRODUCTION AND BACKGROUND

For my capstone project, I investigated the effects of higher order cognitive strategies on students' understanding of high school chemistry concepts. The two motivations for this topic, which I discovered through a close reflection on my teaching, are my chemistry students traditionally perform poorly on the final summative assessment, and that my students enjoy working on the hands-on experiences as part of the course, but they often are unable to connect what we do in the laboratory to other experiences. These factors demonstrated a need for better student understanding of chemistry concepts and increase of their long-term memory of concepts. I felt that if my students understood the concepts better and remembered them for a longer period of time, they could perform better on summative assessments and relate concepts to each other better.

I also wanted to help my students develop an appreciation of how chemistry is important to them. This was significant to me because if I could help my students with this, they would be more likely to appreciate chemistry in their lives as they better understood the higher levels of cognition. The far reaching impact that this had ranged from a better preparedness of chemistry for college conceptually, as well as overall cognitive gains. The results of this project has other impacts as well, because I could communicate my findings to my colleagues and provide an avenue for increased understanding on higher order thinking and other subjects to help better students learn science.

My project focus question was, what are the effects of higher cognitive strategies on students' understanding of chemistry concepts? The project subquestions are as follows: what the effects of higher order cognitive strategies are on students' abilities to answer

higher order cognitive questions; what are the effects of higher order cognitive strategies on students' long-term memory of concepts; what are the effects of higher order cognitive strategies on students' attitudes toward learning chemistry; and what are the effects higher order cognitive strategies on my attitudes toward the planning and implementation of chemistry units as well as my perceptions of teaching chemistry?

For this project, higher order cognitive strategies, further referred to as HOCS, are strategies of cognition, which require students to apply concepts that they learn, analyze data and conclusions and evaluate chemistry and scientific claims. Using HOCS required students to rely on content knowledge and essential questions that they learn during the unit, but also to meld the knowledge with other areas of learning to demonstrate deep understanding of chemistry concepts.

My school is an interdistrict magnet school located in suburban Hartford, CT. The students range from 6^{th} grade through 12^{th} grade. They come from very diverse backgrounds, ranging from students who receive free and reduced lunches and live in some of the poorest sections of Hartford to students who come from very affluent families in more affluent communities. The specific subject that this project is aimed toward is college preparatory chemistry, a course that most students enroll in. I generally teach 90% to 95% of the students who attend our high school.

A great team of teachers and friends have been invaluable to me toward the development of this project. Dr. Christian Bahn, Chemistry Professor at Montana State University has assisted in the development of content related data collection instruments. Dr. Barbara Liu, English Professor from Eastern Connecticut State University, Kimberley

Orr, Education Instructor at the University of Lethbridge, CA, Jennifer Hood, Biology Instructor in Tennessee, and my wife, Kari Percoski are my support and critical team members towards the writing of this paper. Dr. Jewel Reuter from Montana State University, has been an invaluable member of my team, serving as my mentor, role model, and critical friend through all facets of this project. I feel I have one of the best possible teams that have guided me through this project.

CONCEPTUAL FRAMEWORK

In order to determine if HOCS affect students' understanding of chemistry concepts, the focus of the students will be on their application, analysis, and evaluation of chemistry. The themes presented will indicate how HOCS help the student to engage in higher order cognitive processes and as their abilities to remember concepts taught in chemistry. Possible effects of HOCS on the student will be investigated as well as effects on my planning and producing units. There is sufficient evidence to suggest that organizing a unit of study with HOCS will assist in students' abilities to answer higher order cognitive questions and remember concepts in the long-term.

HOCS have many benefits to the learning processes of students. According to Barak, Carson, and Zoller (2007), "promoting higher order cognitive skills and 'making connections' between everyday life issues and the topics taught in class are becoming prominent in contemporary chemistry learning and teaching in the past decade" (p.1712). Danili and Reid (2004) discussed two types of learning individuals, field-dependent and field-independent learners. The term, field, has to do with working within the content

area. In correlating to Bloom's taxonomy (Bloom, 1956), a field-independent individual would be the individual who is able to successfully think and complete tasks that require the higher levels of the taxonomy; whereas, a field-dependent individual would only be successfully complete tasks on the lower end of the taxonomy.

By asking higher order cognitive questions and completing higher order cognitive activities, it is possible to move students' from the realm of field dependency to field independence. This will also encourage them to create connections between learning concepts and their learning and their world. Zoller (2002) completed an independent study of freshman college students and preservice chemistry teachers to determine a connection between HOCS and answering HOCS exam questions. He noted that most students achieved success in answering algorithmic style questions (exercises) while only moderate levels of success on HOCS questions. A low percentage of students performed well on LOCS (lower order cognitive strategies). It was noted through student interviews that students had preference to the styles of questions in the reverse order. Zoller noted that this is due mostly to many students desiring a single exact answer, rather than several possibilities. However, Zoller also noted that students appreciated HOCS questions.

It is a valuable skill for students to connect their learning to their world, because it helps to establish long-term memory of the concepts studied. Johnstone (1993) proposed a mechanism for learning chemistry, which assists students in putting information into their long-term memory. He proposed that all external phenomena are perceived by the person, and after it is perceived, it goes to short-term, or working memory where we subconsciously decode, encode, match, link, and store some of the information that we perceive. Once in the long-term memory, it can be recalled when necessary and related to

other concepts, ideas and phenomena perceived in other processes. This endless cycle aids individuals' long-term memory of concepts, whether directly related and tied into content or not. Therefore, linking concepts is possible, and using this model can help to promote putting concepts into long-term memory. They key is to make the concepts meaningful and connective to each other.

Barack, Carson, and Zoller (2007) wrote,

> Learning activities that require reading and analysis of newspaper articles as an integral component of a course have the potential to bridge the gap between scientific theories and real-world issues as well as promoting the relevant HOCS for students to develop. (p.1712)

Costu, Ayas, and Niaz (2009) completed a study in which 52 undergraduate chemistry students in an introductory chemistry course were asked to complete a variation of the Predict, Observe, Explain (POE) model of understanding. The root of the POE model is that students must tap into higher order thinking skills to adequately work their way through this level of understanding. The students were asked to work their way through an understanding of the evaporation concept. As a result of the study, it was determined that 21 of 22 questions assessed on the posttest and delayed posttest demonstrated retention. By working through the POE model, and thus using HOCS, it is plausible that applying HOCS to the subjects of my study would demonstrate similar data and therefore demonstrate long-term memory.

My students generally prefer hands-on activities; however, the attitudes that they show do not necessarily reflect their attitudes toward chemistry as a whole. In the study by Abrahams and Millar (2008) with 25 case studies involving students aged 11 to 18 in

different settings, it was pointed out that the teachers who implemented the lessons generally focused on completing the task and getting results with little emphasis placed on analyzing or evaluating the results to something more meaningful. According to the study, this directly impacts the attitudes of the students because if they are unable to understand why they are doing something, they are essentially completing tasks with no meaning. Also, getting a result that is meant to happen in a lab can be positive feedback for students, but it doesn't necessarily show learning. It was theorized that students analyzing the process of the activities being completed, reflecting on those processes, and receiving feedback about their performance can contribute to their overall attitudes and motivation. By using HOCS, the students constantly work through learning processes, and not just end results. Johnstone (1993) wrote,

> Our students are like drivers in a strange town who don't know what to attend and, in trying to process too much, they overload. Their [long-term memory] network is not yet well enough developed to enable them to be discriminating. Under these conditions, frustration and bewilderment grow, while enjoyment wanes. (p. 704)

This holds true in nonexperimental activities as well. As indicated earlier by Zoller (2002), it is not only laboratory and hands activities that allow students to connect HOCS and learn from it, but also in assessment styles of questioning. Additionally, the possibility is there for students when they are reading or writing science content, as discussed by Grimberg and Hand (2009). They reported that higher order thinking was "extensively used in the decision-making inquiry and less used in the application activity" (p. 503). This further supports my belief that expecting students to think about

and considering real-life situations will help them to connect to the chemistry concepts better, help them improve their understanding, and enable them to have a positive attitude toward chemistry as a subject.

Helping students to connect the activities they do to other areas in the chemistry class can help them to put the concepts into their long-term memory, and also improve their attitudes as learners of chemistry, as supported by the literature. It was pointed out by Johnstone (1993),

> How much of the effort could be saved if our teaching/learning innovations were theory driven? The theory need not be 'correct' (no theory is) but if it gives direction to our efforts which turn out to be more successful than not, then that theory is useful. (p. 704)

This idea is a shift for me as well. However, it is comforting to know that I will be able to simply shift my planning and implementation on the lessons, and not on pedagogy to have this concept affect my teaching in the long run. I am confident that by planning and implementing lessons in terms of HOCS, I will be able to teach according to the constructivist model which I prefer now, but will be teaching better per HOCS.

Constant reflection on this theory and practice concept will help me to shape my attitudes of science education. By looking at my lessons deeply as they are going on, as well as after completion will allow me to examine how I feel about HOCS in my classroom. Through this capstone project, it is possible that I will experience a similar pedagogical shift, as discussed by McGregor and Gunter (2006). In the study, 173 secondary level teachers participated in professional development in which an emphasis was placed on similar HOCS that I am researching, only introducing teachers to subtle

changes in open-ended questioning. In the results, there was an increase in teachers' asking of open-ended questions, providing opportunities for scientific predictions and articulating conclusions. One respondent wrote, "now we think about teaching and learning in a completely different way…and our KS3 SAT (Standardized Assessment Tasks) scores of level 5 or better went from 53% to 83%" (p. 40). Other general comments indicated widespread changes in questioning and avoiding the trap of providing correct answers. All of this supports that a consideration of looking toward the end and thinking about increasing students' higher order cognitive skills also affects the attitudes of the teacher in a positive way.

It is evident that a higher order cognitive approach to teaching and learning has many potential benefits to the student. Bridging the gap between lower-level cognitive strategies and higher-level cognitive strategies can be achieved by constantly keeping in mind the fact that learning is a process across a continuum. Focusing the attention on connecting the learning to other content areas, as well as real-world situations, should help the students in their overall understanding of chemistry concepts. Additionally, meaningful HOCS will aid the students' in the learning because they will have a more vested interest in the learning and their attitudes and motivations will increase.

Additionally, in this project it is the hope that there will be a profound effect on the attitude and motivation of the instructor. I has been pointed out that efficacy of a new teaching strategy can be very positive for a teacher. Davies (2004) points out that "teachers with a higher sense of efficacy are less critical of students when they make mistakes and exhibit more enthusiasm about teaching" (p. 2). He went on to write that

> Furthermore, efficacy teachers were more likely to have had success with higher order objectives and outcomes with students in the past because such teachers would make greater efforts to achieve them, would persist in the face of difficulties and were better able to cope emotionally with problems that arose. (p. 3)

Because of this study, and the various studies that Davies referenced through his paper, there is more than sufficient evidence to suggest that teaching with HOCS will increase self-efficacy and, therefore, positive attitudes of my teaching.

METHODOLOGY

Project Treatment

For this project, a nontreatment and a treatment unit provided an opportunity for comparison and conclusions about the changes that were implemented. During the nontreatment unit, the students learned about the properties of solutions and it was taught through direct instruction, experimentation, and practice with concepts and problems. The treatment units were based on the ideal gas law and thermochemistry, and were taught with an emphasis on HOCS. The students were asked higher order cognitive questions during lessons, requiring the students to use higher levels of Bloom's Taxonomy.

The students first studied solutions as a nontreatment unit. I delivered this instruction through the use of a pre and postunit summative assessment, worksheets, practice with situational questions and problems, informal formative assessments and lecture. The sources of most of the materials came from example problems and worksheets that

supported the textbook that I use for my class, Addison Wesley Chemistry (Wilbraham, Staley, Matta, & Waterman, 2002).

The unit began by asking the students to define solution and to consider different types of solutions that existed, and how solutions could be made different. I taught the students, via direct instruction, about the concept of molarity as a means of determining concentration. The students then practiced molartity calculations. The next day, students performed an experiment to determine the concentration of an unknown acid in moles per liter. On the next day, students were exposed to the concepts of miscibility, solubility of a solute in a solvent, and temperature effects on dissolution. The students completed a textbook resource in which they analyzed the solubility data for 13 different substances in water at different temperatures, and constructed the solubility curves to go along with them. The handout that supported this lesson can be found in Appendix A. Finally, the students took a performance assessment on the final day of the nontreatment unit where they determined the percent acetic acid in store grade vinegar.

During the nontreatment unit, the students were required to determine the concentration of an unknown acid solution (store grade vinegar) from a known concentration of base solution. This activity provided the students with a definite procedure, and indicated the types and order of calculations that were required to determine the concentration of the unknown acid. Additionally, the experiment included postunit questions that required the students to use the data from the experiment to answer a question. Finally, there was an additional calculation that required the students to follow the same method as the experiment with data that they were given in order to determine the concentration of a different unknown acid. This was taken from a lab

manual in my class, Fundamentals of Chemistry in the Laboratory, Fourth Edition by Burns and it can be found in Appendix B.

For the intervention, I implemented a constant use of high-level cognitive questions and thinking strategies based on Bloom's Taxonomy of the Cognitive Domain throughout the presented lessons. The rationale was that the students connected better with their learning, developed HOCS, and gained a deeper understanding of chemistry. This was the case for each of the treatment units described.

The emphasis for these units was placed on how the students used higher order cognitive strategies; however, they will need to have lower order cognitive strategies to reach higher order strategies. Throughout each of the units, the students acquired the lower order cognitive strategies through classroom discussion, homework assignments and classroom activities. They then utilized the skills acquired from the lower order and apply them to higher order thinking areas. Specific activities that I will employ that will use the HOCS will be progressive concept mapping, case study based experimentation, and higher order cognitive questioning techniques. During the treatment, I emphasized to my students the following vocabulary: skills, techniques, and practice. When students heard these terms, they knew that they were working in a cognitive domain that required them to simply acquire knowledge and understanding. This was lower order cognitive thinking. As the treatment lessons and units progressed, I instructed students to apply the skills, techniques and practice that they acquired in order to answer the higher order cognitive questions and complete higher order cognitive tasks.

One strategy that I used during each of the treatment units was daily progressive concept mapping. The students constructed their concept maps with the terms that were

introduced on the first day of the unit, and added to their maps as new terms were taught to develop the map. This formatively guided students around the misconceptions of concepts as well as helped the students to make the connections and cross links between terms, deepening their understanding of the concepts. For each of the treatment units, there was a large amount of key vocabulary that the students needed to know and understand in order to apply it to newer and more challenging situations. I emphasized the connections between terms for the students, and this guided them in their understandings of the concepts taught. I asked them to connect terms to each other, and because they were asked to cross-link terms, they used higher order cognitive strategies to formulate an understanding of the concepts. This strategy provided the students with the opportunity to reflect upon their own understanding of the concepts that they are being taught.

Several other activities were completed as the units progressed, which involved manipulatives and real-life experiences. For example, students were presented with case studies that required students to apply the lower order skills that they have acquired to more complicated situations that will require a demonstration of the knowledge, rather than mere regurgitation. As supported by the literature review, students prefer to answer questions that have a definite answer and which only have a small number of ways to arrive at it. However, during the treatment units, the students were asked to work through very large problems that required application and evaluation of all of the knowledge of the concepts that they had. Throughout the procedures or instructions of each activity, students were prompted with questions about the processes being completed, tying directly into the unit objectives and based on the tasks that they completed. This was used

in lieu of only answering questions to check for knowledge acquisition, which is within the lower order cognitive domain. Upon completion of tasks such as this, the students articulated a conclusion or conclusions about what they did and they reflected upon their learning. I asked students to deeply explain their thought processes within their learning, and this provided them the chance to consider how they were thinking. Requiring the students to justify their thinking was also a higher order cognitive task because it helped students to look back on what they did and explain their reasoning.

Throughout the unit, I asked the students to answer higher order cognitive questions that required them to apply and analyze the information that they acquired. For example, a student may be presented with a question that required them to explain their answer utilizing the information that they are presented with. In order to be successful in this task, the student must have acquired the knowledge, must have understood what they learned, and they must have used it in a new way. The ability for my students to be able to do this was part of the treatment units and measured throughout.

One example of a treatment lesson that my students did was a situation in which they were required to determine the pressure on the inside of an aluminum soda can. This lesson was part of the treatment unit about the gas laws and it required them to have an understanding of the ideal gas law in order to answer the question. The students were given one can of soda and any other materials in the lab that they wanted. In order to be successful, the students needed to appropriately measure the volume of gas inside of the can, temperature of the gas and number of moles of gas that were inside of the can. This activity is higher order in nature because it requires the students to not only understand what the ideal gas law is, but it also requires the students to be able to determine how to

collect the appropriate data that they need to determine the pressure on the inside of the soda can, and then to finally use the data that they collected in order to calculate the pressure. This experiment emphasizes the higher order cognitive process and not the correct answer, as it is nearly impossible to determine the actual pressure on the inside of the soda can. This also challenges the students to find an appropriate answer to a question in which they will only have one chance to make the experiment work. Constant reflection through the experiment was the route to success for the students, and therefore the high cognitive domains were necessary for students to think and plan ahead.

Another example of a treatment lesson for the students was presented as a case study, and was to determine which of a series of soluble chemicals would make the most effective cold pack when mixed with water. In order to complete this exercise, the students needed to have knowledge of how enthalpies of solutions were determined, how to determine the amount of heat in something, an understanding of the necessary data that they needed to collect as well as the appropriate method to collect the necessary data. Finally, they needed to ensure that they were collecting consistent and controlled data so that they could draw a comparison between the different chemicals. They then needed to articulate a conclusion to answer the question that was asked from the beginning. Each of these important aspects of the task required higher order thinking because they needed to apply their learning, evaluate their results and create an experiment to solve the question that was initially asked.

Data Collection Instruments

The students participating in this study were 11th grade students who intend to pursue a college education. Two classes were studied for eight weeks. There were a total of 26

students in the class. Sixteen of the students were Black, 4 were White, 5 were Hispanic, and 1 was an Asian exchange student, and there were ten male students and sixteen female students. Most of the students enrolled in our school in sixth grade. None of the students are new to the school this year. The students' classes are in a daily 90 minute block schedule and the students meet for half of the year. Of the students in the group, nine of them were in the honors biology section in the previous school year; however, due to scheduling conflicts there was no honors chemistry group. Thus, the students were heterogeneously grouped. Additionally, all of the students scored proficient or better on the Connecticut Academic Performance Tests. The test is a basic skills test, and scoring proficient on the test indicates community college readiness. These students were chosen because of their intentions of pursuing higher education. I tracked the data for low-achieving, middle-achieving, and high-achieving students as determined by grades from the previous marking period and current standing in the class to determine if there is a correlation between the intervention and ability of the students overall.

I collected five types of data during this project to form a conclusion about my project questions. These are shown in Table 1 as a triangulation matrix. The triangulation matrix allowed me to gain a full perspective of how effectively each project question was answered as well as how effectively the focus question were answered by answering each research question in different contexts. The mix of data allowed me to gain a full appreciation of each focus question and how multiple data can support each question.

I collected data about students' understanding of concepts through the use of pre and postunit assessments, student interviews about their understanding of the concepts and student surveys. The pre and postunit assessments provided data about what level of

understanding students had of the concepts. The nontreatment pre, post, and delayed unit assessments are in Appendix C and the intervention pre, post, and delayed unit assessments are in Appendices D and E. The interview questions were done with a heterogeneous group of students, and the questions were asked to find out what the students' perceptions about their understanding were. This can be found in Appendix F. Finally, I used anonymous surveys through an internet based survey tool to determine overall student understanding of the concepts. The survey used open-ended questions and Likert scale questions. The survey questions can be found in Appendix G.

Table 1
Data Triangulation Matrix

Project Question	Data Source		
	1	2	3
Understanding concepts	Preunit and postunit assessments for both nontreatment and treatment units	Preunit and postunit concept interviews questions from six students per class; 2 high, 2 middle and 2 low-achieving students	Preunit and postunit perception of understanding concepts based on interview questions and survey questions
Answering Higher Order Questions	Preunit and postunit higher order assessment questions for nontreatment and treatment units. Classifying students' placement in the various levels of the cognitive domain	Preunit and postunit higher order assessment interviews questions and paper based interview questions on assessments	Preunit and postunit perception of understanding of higher order questions and survey questions, observations and personal journal entries
Long-term memory	Postunit and delayed unit assessments	Postunit and delayed unit paper-based interview concept questions	Postunit and delayed unit perception of long-term memory

Attitudes toward chemistry	Student survey results for both nontreatment and treatment units	Observations and quotes from students during lessons	Student attitudes from interview results for nontreatment and treatment units
Planning, implementation and perception of my teaching.	Daily journal entries for nontreatment and treatment units	Results from student interviews based on nontreatment and treatment units	Results from student surveys based on nontreatment and treatment units

To assess students' ability to answer higher order cognitive questions, I used the same pre and postunit assessments, weekly student interviews and surveys, and journal entries. The pre and postunit assessments informed of the degree to which students answered the higher order cognitive questions. The interview questions and surveys of students allowed me to determine how students perceived the higher order cognitive questions. Interviews were conducted of two high-achieving (exemplary), two middle-achieving (goal) and two low-achieving (proficient or below) students, as measured by the Connecticut Academic Performance Test results. All students took the anonymous survey. The journal entries were open-ended questions that served as the engagement exercises from previous class settings. Sample journal prompts can be found in Appendix H. These enabled me to check for students' understanding as the unit was progressing, and their ability to answer higher order cognitive questions within the unit.

To check for students' long-term memory of the concepts, I used delayed postunit assessments, delayed interview questions, and surveys to determine students' perceptions of their long-term memory. The delayed assessment, which were the same as the pre and post assessments, gave me concrete data as to what students understand and remembered and were given 14 days after the completion of the units. The interview questions

allowed me to hear the students' actual words in terms of what they remember, and I was also able to use verbal and nonverbal cues to recognize this with the students. The surveys were an anonymous way of determining how the students' perceive their memory of the concepts.

In order to determine the students' attitudes toward chemistry from this intervention, I collected the data in anonymous surveys, through the words that come out of their mouths during actual lessons as I observe them, and through interview questions. The surveys provided an anonymous look at how students are perceiving chemistry as a result of this intervention. As a member of the class, my observations of the students' attitudes and the words that they say indicated excellent formative data about their attitudes in the course. Finally, the interview questions allowed me to determine their attitudes toward the intervention and chemistry as a whole.

In order to determine my attitudes toward the intervention, I used prompted journal entries, results from student interviews and anonymous student surveys. The journal entries were written by me daily, and the prompts for the journal entries are found in Appendix I. These data were important because it demonstrated my reactions and feelings toward the intervention immediately. I looked for trends in my understanding as the intervention progresses. The interviews and surveys were a way for my students to tell me how they feel about my attitudes. I believed this was important because they were my hardest critics, and hearing what they had to say about my perceptions was important to the overall process.

Over the project, I looked at qualitative and quantitative data in order to determine if this intervention was meaningful and successful for the students. I used the student

interviews to look for trends across the students regarding both their attitudes toward the intervention and my attitudes toward the intervention, as well as their overall levels of understanding based upon the intervention. Because I analyzed the data from students of all ability levels, I was provided with a good snapshot of where the class is as a whole.

I compared the pre and postunit tests within a unit, as well as across the intervention to recognize what students learned and understood as a result of the intervention. I looked for common verbiage that the students used in responses, and I also looked for articulated answers. It was expected that the students knew very little on the pretest and knew more on the postunit test. However, what was interesting for me was to see the progression in their thinking from assessment to assessment. For example, as I began the intervention, my students did not know what was expected of them regarding the answers that they should give for questions. However, as the intervention progressed, I expected their answers to be of the higher order cognitive variety.

When I looked at the student surveys, I analyzed the data based upon common answers and trends, but also based upon changes in thinking, similar to the pre and postunit assessments. The surveys were anonymous and, therefore, demonstrated in a blind fashion whether or not the class was experiencing a change of thinking as a result of the intervention.

For the teacher journals, I analyzed whether I was showing a change in thinking as a result of implementing the intervention. I noted that the change in thinking went one way or the other, and this was also valuable data. As supported by the literature review, the changes in thinking that I demonstrated should be that of more satisfaction and better overall planning. This was something that I specifically looked for.

The total project spanned a period of approximately four weeks. The nontreatment unit and each of the treatment units will span six school days of 90 minute classes. A sixth day will be used as the summative assessment day for each unit. This totals 20 days of data collection. A summary schedule of the timeline is in Appendix J.

DATA AND ANALYSIS

Data from the nontreatment and treatment unit were compared to determine the effects of HOCS on students' understanding of chemistry concepts as well as each subquestion. The data were triangulated to assess each question and subquestion, which also allowed for a discussion of validity. The use of pre and postunit assessments allowed me to compare the percent change in understanding for the nontreatment and treatment units. Also, qualitative data from student interviews and surveys were used to assess the understanding of the concepts. Data from the pre and postunit assessment can be found in Table 2. The results show an increase in conceptual gains for the Treatment Unit 1 compared to the nontreatment units and approximately equal gains in Treatment Unit 2.

Table 2
Pre and Postunit Assessment Data Reported in Percents (N=26)

Description of Data	Nontreatment	Treatment I	Treatment 2
Preassessment Average	24	8	22
Postassessment Average	70	66	64
Percent Change	192%	725%	191%

Interviews were conducted of students about the concepts for each of the units. Responses were taken from each of the nontreatment and treatment units, and there were responses that were gathered from two low-achieving, two middle-achieving and two high-achieving students. Sample responses from the students are tabulated in Table 3.

Table 3
Student Pre and Postunit Interview Responses About HOCS and Understanding Concepts (N=6)

Description of Data	Nontreatment	Treatment I	Treatment 2	Trend
Low-Achieving Preunit Interview	"I have no idea what the parts of a solution are."	"It probably has something to do with kinetic and potential energy"	"Hot is like something that is hot and cold is something that is not hot"	More deep discussion using concept terms.
Low-Achieving Postunit Interview	"The two parts of the solution are solubility and whether it is polar or not"	"It describes kinetic energy and how things like molecules move"	"I might think something is hot, but you might think it is not hot, but not necessarily cold."	Scientific terms are more deeply described in treatment units.
Middle-Achieving Preunit Interview	"The parts are water and something in it. If you have more in the water, the concentration is more."	"It has to do with what we think about energy and movement because it is a theory."	"Hot is a lot of energy and cold is not a lot of energy. Something can be hot but cold at the same time."	Student responses from treatment units relate more to concepts than generalities.
Middle-Achieving Postunit	"The more solute you have the higher the concentration"	"It helps to explain everything about gases	"Cold is not really anything, but just a different way	Comparison between terms is scientifically

Interview		like pressure and volume”	of saying not as hot”	based for treatment units.
High-Achieving Preunit Interview	“Concentration is amount of solute compared to amount of solvent.”	“I probably has to do with the movements of molecules and what we think about them because of movement”	“Everybody has a different idea of hot and cold, but I’m not too sure what you mean about scientifically.”	Students are less sure of the answers from the treatment units than nontreatment
High-Achieving Postunit Interview	“Solute and solvent ratios describe concentrations, so if you have a greater ratio of solute to solvent, concentration is more”	“The kinetic theory relates energy to how the molecules of gases move and things like pressure, volume and temperature.”	“Heat is just amount of energy, and most think of heat and temperature as the same. When we say cold, we mean temperature, even though there might be a lot of heat”	Treatment responses are much deeper in understanding and explanation than nontreatment responses.

Data were also collected to determine student perceptions of their understanding from surveys. Likert scale questions were used to collect this data. Summary of the Likert scale data, which were on a scale of 1- 5, with 5 being the strongest agreement are in Table 4. These data indicate little overall change in the students’ perception of their understanding, despite some very small gains in agreement for the treatment units.

Question 1, regarding student perception of their understanding, demonstrate that they have a stronger understanding of the objectives of a unit when it is taught with HOCS. There was less strong evidence to suggest that the students understood how the objectives

were important to their understanding, from question 2. Finally, there was no evidence to suggest that the students understood how the learning objectives helped them to appreciate chemistry in their world from question three.

Table 4
Student Survey Responses Regarding Understanding Chemistry Concepts (N=26)

Survey Question	Nontreatment	Treatment 1	Treatment 2
Question 1 Average Score	3.12	3.54	3.37
Question 2 Average Score	3.64	3.77	3.63
Question 3 Average Score	3.64	3.62	3.59

Note. 5=highest understanding and 1=lowest understanding.

Overall there is not strong evidence to suggest that HOCS help students to understand chemistry concepts from the pre and postunit assessment data. There is a great increase in the percent difference from the preunit assessment to postunit assessment for the nontreatment unit versus treatment unit 1; however, there is little difference between the nontreatment unit and treatment unit 2 and a decline from treatment unit 1 to treatment unit 2.

A possible explanation of this is that several of my students are currently in my AP Biology class and this unit was previously taught in their curriculum. This inflated the preassessment score and, therefore, gave the nontreatment an advantage over the treatment units.

Quality of student responses for interview questions demonstrated a great increase for student understanding through the use of HOCS. The strongest evidence for this is the fact that the student responses use far more scientific vocabulary in the postunit interview treatment questions than they do in the preunit interview treatment questions, specifically for the low and middle-achieving students. While the high-achieving students demonstrated an understanding of the concepts better, it was the low and middle-achieving students who used much stronger vocabulary and higher quality responses.

In order to assess students' ability to answer higher order questions, data were collected from pre and postunit assessments, interview questions, and student perceptions from surveys given before and after each of the nontreatment and treatment units were completed. Triangulating these data allowed for a determination about whether or not teaching with HOCS in mind helps students to be able to answer the higher order questions. Data from pre and postunit tests are in Table 5.

Table 5
Students' Assessment Percent Score in Answering HOC Questions (N=26)

Description of Data	Nontreatment	Treatment 1	Treatment 2
Pretest Attempted Questions	0	52%	60%
Pretest Correct Answer	0	0	0
Posttest Attempted Questions	84%	88%	100%
Posttest Correct Answer	32%	60%	48%

The first important thing to note is the fact that students were not able to answer higher order questions at all in any of the units. Therefore, there is a great change in the number of correct answers of higher order cognitive questions for the posttests. The number of students who attempted the higher order question on the pretest increased significantly, and there were modest gains on the posttest.

Students were also interviewed with a higher order question before and after the each of the units. The students were asked to construct a concept map of the important concepts from the unit. Overall, the concept maps were weak in terms of cross linking and hierarchical structure, however, the students had included many interesting propositions. Students were interviewed based on low, medium, and high-achieving ability level. Note that there are no data for the nontreatment unit due to extenuating circumstances. A summary of student proposition data are summarized in Table 6.

Table 6
Pre and Postunit Assessment Concept Map Proposition Accuracy of Low, Middle, and High-Achieving Students (N=6)

Description of Data	Nontreatment (6 Concepts)	Treatment 1 (8 concepts)	Treatment 2 (8 concepts)
Low-Achieving Preassessment Accurate Propositions	-	2	0
Low-Achieving Postassessment Accurate Propositions	-	12	13
Middle-Achieving Preassessment Accurate Propositions	-	1	4
Middle-Achieving Postassessment Accurate Propositions	-	15	14
High-Achieving Preassessment Accurate	-	3	7

Propositions			
High-Achieving Postassessment Accurate Propositions	-	13	14

From these data, it is easy to see that posttest propositions are more accurate for the students than pretest propositions. The more telling data, however, are the fact that the low-achieving students were able to answer the higher order questions with a greater increase than the middle or high-achieving students. Not only did they demonstrate the greatest overall increase, but they also leveled off at the same level as the middle and high-achieving students.

Results from the Likert Scale Surveys demonstrated students' perceptions on their ability to answer higher order questions. A summary of the data from the student surveys is in Table 7.

Table 7
Survey Responses of Student Perceptions of Answering Higher Order Questions (N=26)

Survey Question	Nontreatment	Treatment 1	Treatment 2
Question 4 Average Score	3.40	3.76	3.84

Note. 5=highest understanding and 1=lowest understanding.

There is a growth in students' understanding of how they used information, as evident from the Likert Scale. There is an overall upward progression in the students' perception of their understanding of the information.

In addition to the survey questions, students demonstrated their perceptions about answering higher order questions in reflection questions. Sample responses from student

reflections about answering higher order questions are tabulated in Table 8. For the purposes of fair comparison, sample responses were taken from the same students. Student responses are compared side by side in the table.

Table 8
Sample Responses from Student Reflective Journaling about Answering HOC Questions (N=4)

Description of Data	Nontreatment Sample Response	Treatment 1 Sample Response	Treatment 2 Sample Response	Trend
Student Reflective Journal Prompt 5	"It helps me realize I worked to my ability."	I feel pretty comfortable using the skills. It allows us to expand our thinking and answer harder questions."	"I am very comfortable. I feel that I was able to fully answer each question effectively"	Students feel better about answering treatment HOC questions.
	"I don't mind answering questions as long as I know what it is"	"I feel comfortable because our work in class has given me the ability to look at material from different perspectives"	"It makes me work harder which assists in my understanding of it all"	Students feel good about looking at questions from different angles using HOCS
	"I don't feel comfortable because I don't understand the question fully"	"I don't feel comfortable because I don't fully understand this unit."	"I'm not comfortable answering those questions because I don't understand the whole topic."	Uncomfortable across the board because of a lack of understanding overall.
	"I feel about 90% sure of myself; I get	"I feel comfortable because it's easier	"I believe I can apply and	The student generally

	tripped up at times and get frustrated trying to untangle my mistakes and learn from them."	to connect something we learned to an aspect of life than just take notes about it."	create; but I don't know about evaluating."	feels comfortable, regardless of HOCS.

These data show a great progression of student perception from the nontreatment unit to treatment unit 2. The students showed, at the very least, growth in the quality of the responses that they gave. It was very telling for the students to indicate their level of comfort as well as reasons why. For students who did not feel comfortable, the reasons were based on their opinions that they missed the big picture, instead of not understanding pieces of information. The students who felt like they could answer the higher order questions believed it was because they used what they learned to answer the questions.

To determine if HOCS had an effect of students' long-term memory of concepts, data were collected from a delayed assessment, delayed interview questions about concepts, and delayed perception of students' long-term memory. This question can not be fully answered. Due to the end of the school semester occurring, delayed assessments and interviews for treatment 2 were to be collected in the next semester. There were six cancellations of school due to inclement weather in the first couple of weeks of the second semester, and because of administrative decisions on scheduling changes, data could not be collected for treatment 2. Data that were collected, however, are presented as it was collected. A summary of the delayed assessment data are in Table 9.

Table 9
Delayed and Posttest Student Averages Regarding Long-Term Memory in Percentages (N=26)

Description of Data	Nontreatment	Treatment I	Treatment 2
Posttest Average	70	66	No data
Delayed Assessment Average	53	57	No data
Percent Change	-24	-13.6	No data

From the limited data presented, there is evidence to suggest that using HOCS help students to put concepts into their long-term memory better than not using HOCS. Students only lost approximately half as much of the information that they demonstrated understanding from posttest assessment to delayed assessment when comparing the nontreatment unit to the treatment unit. While impossible to extrapolate data, I believe that students would have showed a greater decrease in long-term memory for treatment 2 than treatment 1, but improved from the nontreatment based on evidence presented from the rest of the data. Students appeared to use the concepts more when they used them in the critical thinking activities and this may have accounted for better long-term memory and students were more comfortable using the HOCS in treatment unit 2.

Students were asked an interview question about the concepts after the delayed assessment and this was compared to the responses that students gave after the posttest assessment for both the nontreatment and treatment 1. As noted earlier, the interview from treatment 2 was not completed and no data were collected. Summaries of the responses are in Table 10.

Table 10
Delayed Interview Student Responses Checking for Long-Term Memory (N=6)

Description of Data	Nontreatment	Treatment I	Treatment 2	Trend
Low-Achieving Postunit Interview	"The two parts of the solution are solubility and whether it is polar or not"	"It describes kinetic energy and how things like molecules move"	"I might think something is hot, but you might think it is not hot, but not necessarily cold."	Scientific terms are more deeply described in treatment units.
Low-Achieving Delayed Interview	"I don't really remember what this is except water and something else."	"It is like kinetic energy and why gases move."	No Data	Ability to recall basic information.
Middle-Achieving Postunit Interview	"The more solute you have the higher the concentration"	"It helps to explain everything about gases like pressure and volume"	"Cold is not really anything, but just a different way of saying not as hot"	Comparison between terms is scientifically based for treatment units.
Middle-Achieving Delayed Interview	"Solute and solvent and when you have more solute, you have more concentration."	"It is the movement of gas molecules and pressure."	No Data	Scientific terms are used less, but the concept is still understood.
High-Achieving Postunit Interview	"Solute and solvent ratios describe concentrations, so if you have a greater ratio of solute to solvent,	"The kinetic theory relates energy to how the molecules of gases move and things like pressure,	"Heat is just amount of energy, and most think of heat and temperature as the same.	Treatment responses are much deeper in understanding and explanation

	concentration is more"	volume and temperature."	When we say cold, we mean temperature, even though there might be a lot of heat"	than nontreatment responses.
High-Achieving Delayed Interview	"The more solute you have, the greater the concentration when you have the same amount of solvent."	"It describes how pressure, volume and temperature are affected by gas molecules."	No Data	Strong recollection of relationships between conceptual terms.

There did not appear to be a major decline in the understanding of any of the students from the posttest to the delayed assessment. Overall, it appeared that the students retained their understanding of the concepts that they learned and that they were able to answer the same interview concept question in a very similar fashion in the delayed interview as they did in the postinterview. However, there is insufficient evidence to suggest that HOCS had a major effect on long-term memory from these data.

Data were collected on students' perception of their long-term memory of the concepts in the surveys as well. While Question 4 of the survey helped to demonstrate student understanding of answering higher order questions, it also addressed their perceptions of understanding chemistry as a whole better, and, thus, long-term memory. A summary is in Table 11.

Table 11
Student Perceptions of Long-Term Memory from Surveys (N=26)

Survey Question Concerning Long-Term Memory	Nontreatment	Treatment I	Treatment 2
Average Score	3.40	3.76	3.84
Delayed Score	3.32	3.64	No Data
Percent Change	-2.35%	-3.19%	No Data

Note. 5=highest understanding and 1=lowest understanding.

I am not confident in the data that is presented about student perceptions of long-term memory from the student surveys. In the nontreatment and treatment 1, the student's average score decreased by 0.08 points. This indicates little change in student perception of their understanding from the postsurvey to the delayed survey. Their opinions about understanding concepts, whether in their long-term memory or not, did not change for better or worse.

Changes in the students' own perceptions of HOCS and their attitudes toward learning chemistry were determined by looking at student Likert scale surveys, observations of the students during the lessons and student attitudes from interviews. Data about the students' attitudes about learning chemistry from HOCS is in Table 12.

Table 12
Student Perceptions of About Attitudes of Learning with HOCS (N=26)

Survey Question	Nontreatment	Treatment I	Treatment 2
Concerning Relating to the World Average Score	3.64	3.62	3.59

Concerning Using Concepts Learned Average Score	3.40	3.76	3.84

Note. 5=highest understanding and 1=lowest understanding.

Generally, students did not seem to appreciate the world via HOCS. This was the root of the question, what are the effects of HOCS on students' attitudes toward learning chemistry, in that if students could understand its connection to the world, then their perceptions of learning with HOCS were expected to increase. It is evident, though, that there is a slight decrease. This can be interpreted as approximately no change, as the average scores are all within 0.05 points of each other. It is apparent that students perceived that they were using the information that they learned in class more and it helped them to understand the chemistry better. There are significant increases from the nontreatment to the treatment units. Additionally, the two treatment units show a very small increase from each other. This is indicative of a very small increase.

Teacher observations of student comments and quotes were collected throughout the units of study to pay close attention to students' perceptions of learning via HOCS. Summaries of the quotes are listed in Table 13.

Table 13
Sample Student Quotes During Nontreatment and Treatment Activities (N=26)

Description of Data	Student Quotes
Nontreatment	"This is so easy. I don't really see the point in it."
	"I can't stand doing stoichiometry. It is so pointless. I am never going to need to use it again after this class."
Treatment 1	"I don't understand how to determine the pressure inside the soda can if I don't know the moles. I have to be able to find the

	moles some way, it's just how."
	"This concept map is really helping me to see how everything goes together, like pressure and volume."
Treatment 2	"The coldest pack would be the one with the greatest loss of energy, so we need to figure that out first."
	"I like how these experiments are making me think, but it is really hard for me to figure out what to do next."

The quotes above are a small sampling of the overall student attitudes. Generally speaking, the students were much more positive in class during the treatment units than they were the nontreatment unit. This was due to the freedom that they had and the responsibility that they had for their own learning. They were comforted to know that, while there is a correct answer, HOCS allow them to use many avenues to get to the correct answer. This gave them a little more freedom and flexibility to work their way through the lessons, and it permitted them to build confidence in their overall understanding of chemistry concepts. Students generally showed frustration about not getting a single answer, but they were more accepting of the reasons for this.

Student interview data are in Table 14. The data are quotes that demonstrate how the students think of their own learning, and as with the earlier interview data, students were interviewed from different ability levels. Data presented in Table 14 are responses to question 7-9 of the interview questions, found in Appendix F.

Table 14
Student Interview Responses about Attitudes in Learning with HOCS (N=6)

Description of Data	Nontreatment	Treatment 1	Treatment 2

Low-Achieving Postinterview Interview	"I feel like I have a general understanding of it, but I could use some more work with it." "6 because I have a basic understanding. I understand the general things, but I could use more with the specifics."	"At times I was successful. I just couldn't fully understand it that well." "6. I got the main ideas, but other than that I didn't really get it all that well."	"Overall, I don't feel like I was successful. I found it very hard to use everything together." "4 or 5. Overall, I just didn't understand this unit."
Middle-Achieving Postinterview Interview	"Most of it. It was basically information that I could use easily." "7-8 because I feel like I did well with it and I was able to use the information."	"Yea. I had some trouble at first but then I understood it, like PV=nRT." "8 or 9 because I could use what we did in class at the end and I felt like I learned a lot from the pre-test."	"I understood all of the main ideas, but I don't feel like I understand the details." "7 because I know the important main ideas, but the details are still something I struggle with."
High-Achieving Postinterview Interview	"I think so because I actually understood what was going on, and I knew more at the end than I did to start." "8-9. I really just felt like I could go through the questions and understand how to do them."	"I feel like I was successful. I feel like I could have done a little bit better, but I didn't work as hard as I could have." "8 or 8.5. I did well with the case studies which showed I could use the information I learned."	"I feel like I was successful, but not as much as the other units we've done. I felt lost at times because we were rushed." "7 or 8. I feel like if we had more time, we could have understood it better."

These data indicate that the students' overall perceptions of HOCS are mixed. Between the nontreatment and the treatment units, the students felt as though their understanding of the concepts increased, but decreased from the first treatment unit to the second treatment unit. Due to the second treatment unit coming right at the end of the course, with the posttest assessment and interview happening the day of the scheduled final exam, the unit had to be pushed to completion. Overall, the students felt a decrease in their understanding from Treatment 1 to Treatment 2.

Determining my own perceptions of teaching using HOCS, data were collected about my perceptions of planning and implementing the units. Personal journal entries were recorded using the prompts from Appendix I. A summary from each prompt is in Table 15 for each unit.

Table 15
Excerpts from Teacher Generated Journal Entries from Prompts (N=1)

Description of Data	Teacher Excerpt Responses
Nontreatment Journal Summaries	"The students are learning the information, but they don't seem to be applying it to anything. They are reaching really high to make connections."
	"I feel like I am naturally expecting my students to learn using HOCS, but they are not at that level. It is probably because I have not taught them how to get there yet, but I feel disappointed in how they are learning."
	"Today, a student alluded to 'hating stoichiometry because [I] will never use it again.'" I want my students to appreciate what they are doing enough to consider the possibility that they may use it again. Also, the purpose was not the stoichiometry – they were already supposed to know that."
	"It is hard for me to not plan with the end in mind – that is HOCS. I feel like I am doing a disservice to my students by not

	using HOCS because I feel so confident in it."
Treatment 1 Journal Summaries	"Good connections were made by students today. For example, they were able to understand why cookbooks have temperature adjustments based on elevation, and they really understood how people in Denver have different lifestyles than people on sea level."
	"I am really happy with how the soda can lab went today. I really put in the time needed to plan it out, foresee the issues that students will have, and consider the questions that I will need to ask to get them to be thinking on a high level. This is a lesson that I plan to refine even more and use again down the road. Next time, I will have my department chair come and do a walkthrough or formal observation on the day of this lesson."
	"Students were really into the pressure cooker case study. They actually were commenting about how they can see the connection between pressure, temperature and volume. They were talking the talk, and that indicated to me that they really understood what they were doing. I was already sold on HOCS lessons, but now I am hooked."
Treatment 2 Journal Summaries	"I find that planning a full HOCS lesson is challenging to do, but the rewards are good in the end. It is the end of the quarter, and the students are getting tired. This is making me adjust my planning, and my HOCS expectations are not reaching the same level. However, I know they can work on that level with good planning, so that just means more effort on my part."
	"Even though I don't feel like my students fully grasped the concepts that they needed to use to analyze their data about the cold packs, I do feel like they had the correct scientific thought in place. They were definitely evaluating what they did (the data they collected) and creating methods to collect the data that they need. Some were discussing how they are going to change their trials to make them work out better for them."
	"Now that I have been cognizant of HOCS for two full units, I feel like I am grasping it well. I know exactly what to expect from the students, I feel like I am beginning to anticipate their questions well, and I feel like I know how to adjust my teaching

> so that I am not giving answers, but guiding students toward an appropriate way of thinking about scientific questions. I feel good about teaching this way when it works well."

These data show a shift in my overall perception due to the planning and implementation of HOCS. Overall, the attitude that was represented in the nontreatment unit was one of helplessness, while the attitude in the treatment units was more hopeful and optimistic. This demonstrates the power of HOCS on the value of the teacher, in that the planning and implementation of HOCS, if done correctly, can motivate the instructor to do well. From the nonmeasured fashion, I simply felt better as a teacher when I was implementing my treatment units than when I was implementing the nontreatment unit.

The second piece of data that were used to determine the overall attitude of planning and perception of my teaching were from student interviews. This data, while useful in a qualitative fashion, is not very demonstrative, nor does it have a great deal of meaning. All students interviewed said the same general thing; that they believed that I enjoyed teaching the unit because I enjoy science and find enjoyment in all that I teach. They also indicated that I made the lessons fun for them because I find teaching fun myself and bring that to the classroom. The opinion was the same from the nontreatment unit and both of the treatment units. I believe this is because the students, despite constant reminders that the interviews would not change my perception of them or their class, felt pressured to tell me what I wanted to hear. I believe that the data are reliable, but I believe the students were more focused on their teacher's personality than they were the overall attitude and demeanor of the class.

The third piece of data to address this area was collected via a Likert Scale survey. The data from the survey are found in Table 16.

Table 16
Student Perception from Surveys of Teacher Attitudes by Using HOCS (N=26)

Survey Question	Nontreatment	Treatment I	Treatment 2
Concerning Teacher Planning and Implementation Average Score	4.44	4.08	4.27
Concerning Teacher Conscious of HOCS Average Score	4.04	4.16	4.31

Note. 5=highest understanding and 1=lowest understanding.

The data from Table 16 are interesting in that there is a large decline in the students' perception of the planning, execution, and teaching of the lesson from the nontreatment unit to the treatment units. I think one of the biggest reasons for this, as alluded to earlier in discussion of the focus question, was that the first unit was one which the students had exposure to prior to the unit beginning. Therefore, it is safe to say that the students' perception about the unit was a bit skewed. However, as the units progressed, the students perceived that the planning improved from treatment unit 1 to treatment unit 2. The interesting thing, when coupled with the rest of the data, is that the students showed a better mastery of treatment unit 1 over treatment unit 2. This would lead one to believe that the execution of the unit was not as good as the previous unit, however, it is also a possibility that the students were more comfortable with using HOCS as a whole.

Additionally, it was comforting to see that the students recognized an increase in using HOCS as the units progressed from nontreatment to treatment units 1 and 2, respectively. This was the anticipated outcome, and it is safe to say that the students were not only getting better with using HOCS, but that they were also expecting it more, making it easier for me to expect more from them.

INTERPRETATION AND CONCLUSION

Data were analyzed to answer the focus question of the effect of HOCS on students' understanding of high school chemistry concepts. The data that were collected from the three units of study suggest mixed results as to the effectiveness of HOCS. However, triangulation of the data collected allowed for some conclusions to be made more definitively. Generally, students felt better about their ability to understand chemistry better through using HOCS and the quality of student responses between the nontreatment and treatment units suggest gains that the students made. It should be noted that there seemed to be a reduction in scores across the board for treatment unit 2 for all areas of this study. A great deal of that, I believe, has to do with the fact that the unit was pushed right to the last day of the semester, and the fact that there was severe winter weather that impeded the educational progress of all students at our school. Simply, the students had lost some of the momentum and motivation of their studies and it may have affected the data that were collected.

Students demonstrated gains in answering HOC questions as a result of project. The quality of student responses on both written assessments and in interviews about HOC questions is higher for the treatment units than for the nontreatment unit. Additionally,

the students were able to draw better connections between concepts through the use of concept mapping in the treatment units than they did for the nontreatment unit. It is apparent that the low-achieving students made the greatest gains with respect to HOC questions because they tended to get into the habit of making connections between subjects to understand the concepts overall. While they demonstrated less overall mastery of the concepts, they showed the greatest gains in answering questions.

It was challenging to assess long-term memory of the students because of weather and end of semester concerns. However, a comparison of the nontreatment unit to treatment unit I suggests that there is more which is retained after 14 days when using HOCS than not. The triangulated data supports this with less conceptual losses on delayed assessments, student responses in delayed interviews, and student perceptions on delayed surveys. This is an area that would require further exploration, perhaps over the course of an entire semester, to truly test the validity of the claim.

While students generally did not forwardly seem to enjoy working with HOCS, the data suggest that they have a preference to it. Students had better attitudes of the course when they were challenged with HOCS than they did when they were not. Student observations helped to demonstrate that the students truly felt challenged by HOCS, and that they would have preferred to have a more easy approach to learning, but that they generally found rewards in working with HOCS. Also, the high-achieving students reacted more favorably toward HOCS than did the middle and low-achieving students. I attribute this to the overall capacity that the students have going in, and the fact that HOCS challenge students to think very widely about concepts. This is an area of struggle for the low-achieving students at my school.

My attitudes were hard to judge from the students. All students believed that I enjoy everything that I do, and that I put on a “happy face” in all classes. They did not really see a difference in my attitude as a result of the implementation of this project. However, I felt much better about my planning and implementation of the project as a result of carrying it through. While the planning was much more challenging, I found myself more engaged in how I can get my students to think deeper and therefore, how I can get them to think better. I truly felt that this project forced me to make my students better thinkers. This is among the greatest nonempirical data that I received as a result of this project because of the fact that not all of my students will go on after high school and pursue a science degree. However, I believe that if I can get them to think more scientifically, critically and with an open mind toward answering HOC problems, then they learned enough in my class to make me satisfied.

There were several challenges that I had in this project that may have affected the results. As written earlier, the students worked on this unit up until the end of the semester. This was a challenge to them because as they were wrapping up their other courses and preparing for finals, they were still working very hard on conceptual understandings in my class. The students took their posttests for treatment unit 2 on the day of the scheduled final exam because they learned straight until the end of the course. I believe this may have contributed to some burn out for the students, and it may have skewed the data for my second treatment unit. If it were possible to start earlier, I would have. However implementing this project in the second semester would also not have been possible due to the constraints of the block schedule in the spring semester as well, and implementation would take place right up to the final exams in June.

Another area that I would change to increase the validity of the data for this project is that I would complete student interviews about concepts in person. While I completed all interviews on paper, thus allowing for consistency, it allowed the students to take the easy way out in answering a question. I was not able to pry the students further and I believe doing so would allow for a better gauge of their understanding.

The one data collection instrument that I am the least confident in is the set of interview questions that I gave. I felt like my students were more interested in telling me what I wanted to hear for answers to interview questions than they were in telling me truthful answers. The greatest question that I struggled with from the interviews were questions having to do with student perceptions of my teaching. The students' answers were much shorter, and they tended to take the approach of the easy way out. Despite my attempts to dig deeper in those questions, the answers were pretty much the same for all three units, and not very informative.

I also felt as thought I could have collected data about HOCS in my interviews differently. I interviewed low, middle, and high-achieving students in pairs so they could feel more comfortable answering questions, but this was limiting when it came to answering the questions. In the future, I will conduct group interviews and then ask the certain specific questions individually for each student.

Of the issues, it is clear that timing and refinement of the interview processes will help to collect better data. When collecting data on HOCS in the future, I will consider these two factors to limit potential pitfalls.

VALUE

This capstone project has afforded me the opportunity to truly develop what is known as the “philosophy of teaching.” I recall as an undergraduate student, I was asked to write my philosophy without really knowing what it was. I feel that teaching with HOCS, and students using HOCS are my philosophy at this point. If students can think at a high level and if I can teach at a high level, then I believe my students will get the most out of my class. As a teacher of chemistry and physics, this is something that I can apply to any subject area. I feel confident in my ability to have students use case studies, consider higher order questions, process difficult concepts and establish creative modes to assist their learning. This is the greatest value that I got out of this project. It is very obvious to me now that I can change the climate of my classroom and help to shape better thinkers by teaching this way.

The results of this project, though mixed, have given me the confidence to report back to my science department what I have learned about HOCS. One consideration for next year is to begin to establish common performance-based assessments to assist teachers in determining to a greater degree what students know and understand about the concepts they are being taught. I have shared with my department my findings, and I am glad that the findings that I reported were one of the catalysts to this shift in department philosophy. Additionally, our school is in the process of being authorized as a Middle Years Programme International Baccaulerate school, and this mode of assessment is central to the IB philosophy. I feel as though I am ahead of the curve in this regard and have been asked to serve as a point person for our department in this initiative.

I feel like the concept of teaching HOCS is one which can be implemented in any classroom, whether science or not. Analysis of literature, solving complex math questions, creating musical arrangements, or developing graphic art are all ways that HOCS can be used. The fundamental concept that this project can be boiled down to are the upper levels of Bloom's taxonomy. All subject areas look to Benjamin Bloom to build the best thinkers and, therefore, the implications of this research are beyond science.

I plan to pursue the concept of HOCS even further because I feel like I am becoming an even stronger teacher than I was before. As a result, I plan to continue the action research by looking at this data over the course of an entire semester. I also plan to use this approach to further develop my curriculum and classroom activities. I also plan to lend my experiences to others to help them develop their curricular materials.

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APPENDICES

APPENDIX A

SOLUBILITY CURVE LESSON HANDOUT

Appendix A

Solubility Curve Lesson Handout

Name _____ Class _____ Date _____

18 INTERPRETING GRAPHICS

USE WITH SECTION 18.1

Solubilities of Some Substances in Water at Various Temperatures

		Solubility (g/100 g of H_2O)			
Substance	**Formula**	**0 °C**	**20 °C**	**50 °C**	**100 °C**
Barium hydroxide	$Ba(OH)_2$	1.67	31.89	—	—
Barium sulfate	$BaSO_4$	0.00019	0.00025	0.00034	—
Calcium hydroxide	$Ca(OH)_2$	0.189	0.173	—	0.07
Lead(II) chloride	$PbCl_2$	0.60	0.99	1.70	—
Lithium carbonate	Li_2CO_3	1.5	1.3	1.1	0.70
Potassium chlorate	$KClO_3$	4.0	7.4	19.3	56.0
Potassium chloride	KCl	27.6	34.0	42.6	57.6
Sodium chloride	NaCl	35.7	36.0	37.0	39.2
Sodium nitrate	$NaNO_3$	74	88.0	114.0	182
Sodium sulfate	Na_2SO_4	4.76	62	50.0	41.0
Silver nitrate	$AgNO_3$	122	222.0	455.0	733
Lithium bromide	LiBr	143.0	166	203	266.0
Cane sugar (sucrose)	$C_{12}H_{22}O_{11}$	179	230.9	260.4	487

A portion of Table 18.1 from your textbook has been reproduced above. Use the table to answer the following questions.

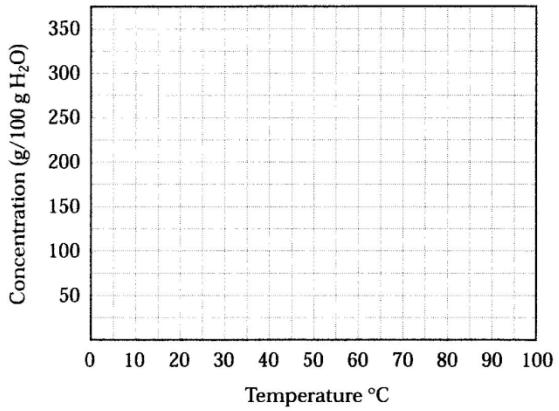
1. Saturated solutions of each of the following compounds are made at 20 °C. Circle the letter(s) of the solution(s) which will form a precipitate upon heating.
   - **a.** NaCl
   - **b.** Na_2SO_4
   - **c.** Li_2CO_3
   - **d.** sucrose
2. A saturated solution of potassium chloride is prepared in 100.0 g of water at 20 °C. If the solution is heated to 50 °C, how much more KCl must be added to obtain a saturated solution?

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Name _____ Class _____ Date _____

3. A saturated solution of sucrose in 1000.0 g of boiling water is cooled to 20 °C. What mass of rock candy will be formed?

4. Using data from the table, plot the solubility curves of KCl, LiBr and Na_2SO_4 on the graph below. Be sure to label each curve. Use the graph to answer the following questions.



a. Which of the compounds is most soluble at 25 °C?

_____

_____

b. Which of the compounds has the lowest solubility at 90 °C?

_____

_____

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APPENDIX B

CONCENTRATION OF UNKNOWN ACID LESSON

Appendix B

Concentration of Unknown Acid Lesson

EXPERIMENT

PERCENTAGE OF ACETIC ACID IN VINEGAR 21

PURPOSE

To analyze commercial vinegar and determine the percentage of acetic acid using volumetric analysis.

PERFORMANCE OBJECTIVES

Following this vinegar analysis, you should be able to perform volumetric analysis on unknown acids using phenolphthalein as an indicator. You should be able to calculate the percentage by weight of the unknown from data obtained.

BACKGROUND EXPLANATION

Volumetric analysis is a very important and standard method of determining the concentrations of solutions. A measured volume of a solution of known concentration is reacted with just enough of the solution with an unknown concentration to cause a complete reaction. Completion of the reaction can be detected by some observable change. The volumetric analysis process is called **titration**.

To minimize errors, volumes of reacting liquids can be measured with great precision to the nearest 0.1 mL and estimated to the nearest 0.01 mL when burets are used. Become familiar with standard methods of cleaning, filling, reading, and operating a buret.

Some type of indicator is used to signal the point of complete reaction. When the reaction involves acid and base neutralization, a pH change can be observed with a pH meter or an indicator solution such as phenolphthalein, methyl orange, methyl red, and so on. These indicators are organic dyes that change color at specific pH intervals. The point at which the indicator changes color is known as the **end point**, the point at which the titration is stopped. If the correct indicator is chosen, then the end point will coincide with the **equivalence point**, which is the exact point when equivalent quantities have reacted. The chemical equation is

$$\underset{\text{acetic acid}}{CH_3COOH} + NaOH \longrightarrow \underset{\text{sodium acetate}}{NaCH_3COO} + H_2O$$

We can see that one mole of acetic acid exactly neutralizes one mole of sodium hydroxide. From the data collected, we can calculate the percentage of acetic acid in a vinegar sample.

[Ex. 21] Percentage of Acetic Acid in Vinegar

Calculations for the percentage of acetic acid in vinegar samples are outlined under the calculations section of the report sheet.

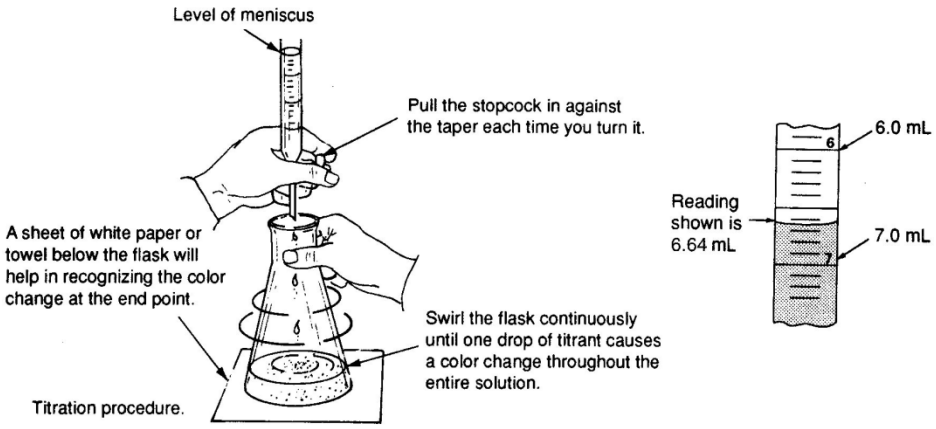
MATERIALS

50 mL buret, 10 mL pipet (or a second 50 mL buret), 250 mL Erlenmeyer flash, wash bottle with distilled water, 0.500 M standard NaOH, and vinegar.

PROCEDURE

Use a clean buret that has been washed with detergent, rinsed with tap water, and distilled water (two samples of 2 mL each). Rinse the clean buret with NaOH (1 to 2 mL). Set up a buret on a buret stand with a buret clamp. Fill the buret to above the 0.00 mL mark with the NaOH solution and let the solution drain out in an extra beaker until the meniscus is on or below the 0.00 mL mark. In a clean Erlenmeyer flask, carefully measure out about 10.0 mL of vinegar from a buret set up on the table where chemicals are dispensed (or use a 10-mL pipet to measure out the vinegar). Record the precise volume of vinegar obtained. Add about 15 mL of distilled water. The amount of water added is not critical because, at the equivalence point, the solution will be neutral, regardless of the amount of distilled water added. Also add 2 drops of phenolphthalein indicator to the flask containing the vinegar and water. Swirl to mix.

Titrate the vinegar with 0.500 M standard NaOH by adding the NaOH slowly, dropwise, to the vinegar solution with swirling action as shown.



As the end point is approached, the pink phenolphthalein color will be more persistent. Near the end point, add titrant (NaOH) *dropwise* with swirling. The end point is reached with the drop that causes the solution to turn pink and remain pink. Record the volume to the nearest 0.01 mL. Repeat the analysis with lab partners taking turns doing the titration. Record your data and calculate the percentage of acetic acid.

Report Sheet _____ _____ _____ _____

Name **Instructor/Section** **Lab Partner** **Date**

Experiment 21: Vinegar Analysis

Data

	Trial 1	Trial 2
1. Vinegar, FINAL reading of buret	_____ mL	_____ mL
2. Vinegar, INITIAL reading of buret	_____ mL	_____ mL
3. VOLUME of VINEGAR used (1 minus 2)	_____ mL	_____ mL
4. NaOH, FINAL reading of buret	_____ mL	_____ mL
5. NaOH, INITIAL reading of buret	_____ mL	_____ mL
6. VOLUME of NaOH used (4 minus 5)	_____ mL	_____ mL
7. Molarity of NaOH used (see label on bottle)	_____ M	_____ M

Calculation of Moles and Percent Acetic Acid

8. Moles of NaOH used _____ mol NaOH _____ mol NaOH
(Liters NaOH used × Molarity in mol/L)

9. Moles of acetic acid in sample _____ mol acid _____ mol acid
(The balanced chemical equation shows that 1 mol of NaOH neutralizes 1 mol of acetic acid, so moles of NaOH and acid, lines 8 and 9, are equal.)

10. Mass of acetic acid in the sample _____ g CH_3COOH _____ g CH_3COOH
(Moles acetic acid × molar mass of acetic acid, CH_3COOH, 60.0 g/mol as shown below)

Method: _____ mol acetic acid $\times \frac{60.0 \text{ g acetic acid}}{1 \text{ mol acetic acid}} =$ _____ g acetic acid, CH_3COOH

11. Mass of vinegar sample used _____ g vinegar _____ g vinegar
(You could weigh the flask before and after you put in the vinegar sample or, more simply, you can calculate the mass of vinegar used by multiplying its volume times its density. The density of the vinegar is 1.005 g/mL.) Sample calculations follow:

Method: _____ mL vinegar $\times \frac{1.005 \text{ g vinegar}}{1 \text{ mL vinegar}} =$ _____ g vinegar

12. **Percent by mass** of acetic acid, CH_3COOH, in the vinegar sample

Method: $\frac{\text{Mass of acetic acid, Line 10}}{\text{Mass of vinegar, Line 11}} \times 100\% =$ _____ % CH_3COOH

_____ % CH_3COOH _____ % CH_3COOH

13. **Average percent** acetic acid by mass _____ % CH_3COOH

APPENDIX C

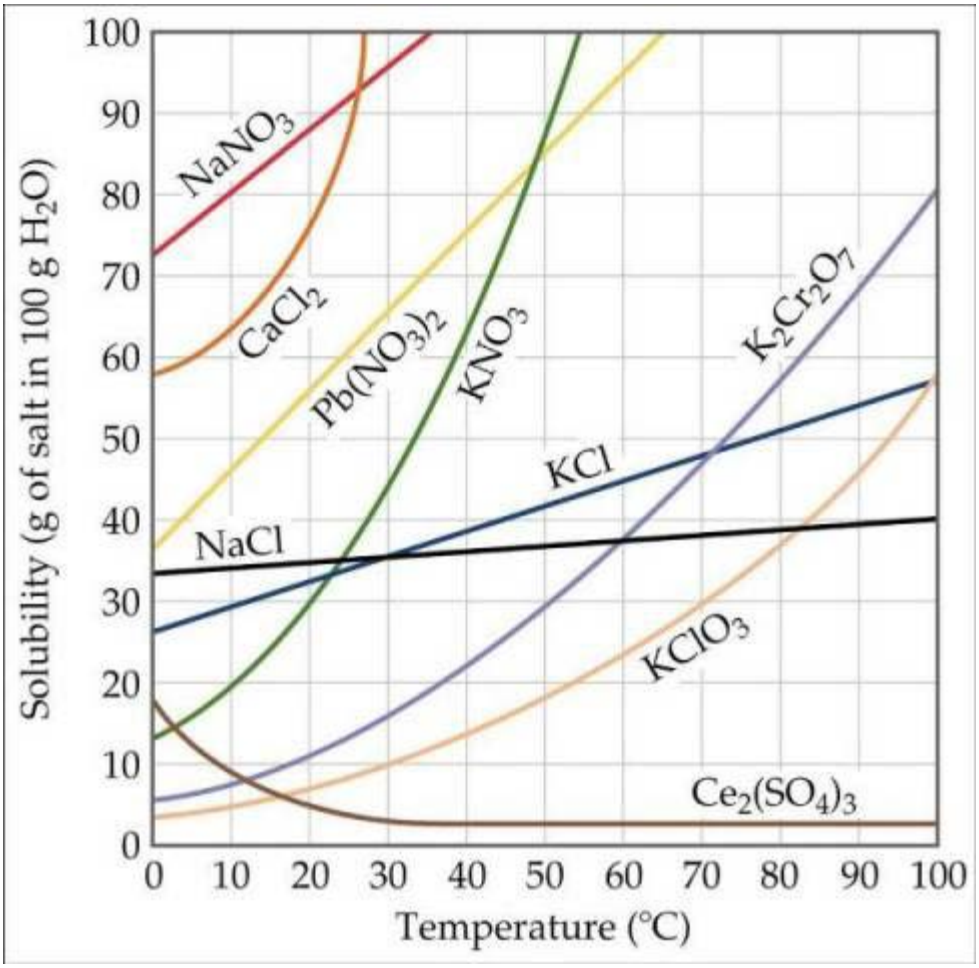
NONTREATMENT PRE AND POSTUNIT AND DELAYED ASSESSMENT - SOLUTIONS

Appendix C

Nontreatment Pre and Postunit Assessment - Solutions

Name: _____

Name and distinguish between the two components of a solution.



According to the solubility curve from above, what is the solubility of each of the following at 40 ^{o}C?

a. $Pb(NO_3)_2$

b. KNO_3

c. $Ce_2(SO_4)_3$

Based on the solubility curve from the previous page, what is significant about cerium sulfate that is different than the other substances? Why is this different than you would expect?

Calculate the number of moles of solute in each of the following solutions:

a. 1.20 L of 18 *M* H_2SO4

b. 10.0 mL of 0.75 *M* $NaClO_3$

Use the following equation to answer the following questions:

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

a. The moles of sodium sulfate produced from 3.6 moles of sulfuric acid

b. the grams of sodium sulfate that can be obtained from 25.0 mL of 0.050 *M* sodium hydroxide

c. the volume of sodium 0.250 M sulfuric acid needed to react with 25.5 mL of 0.750 *M* sodium hydroxide

The principle “Like Dissolves Like” helps to indicate that certain substances will dissolve in other substances. What does this principle mean? Explain and use an example to demonstrate your thinking.

Use the concept of “Like Dissolves Like” to explain how the two polar and miscible substances, water and isopropyl alcohol, could be separated when ammonium chloride was added to the mixture.

APPENDIX D

PRE AND POSTUNIT ASSESSMENT – TREATMENT UNIT I

Appendix D

Pre, Post and Delayed Assessment – Treatment I

Name: _____

Using the principles of the kinetic molecular theory, explain why gases are less dense than solids or liquids.

Create a concept map that addresses the relationship between the following terms: gas, pressure, volume, moles, temperature, ideal gas law, kinetic molecular theory, highly compressible. I have started the concept map for you. You may include extra terms.



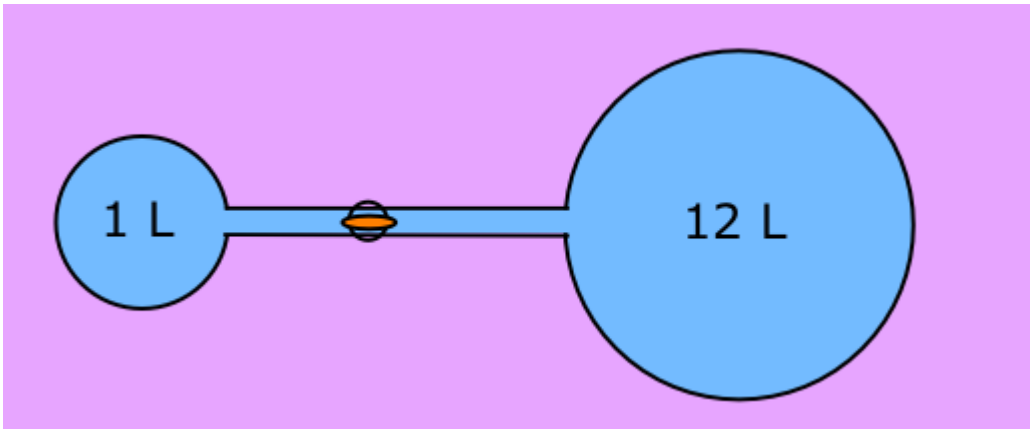
One of the methods for predicting the temperature of the center of the sun is to use the ideal gas law. If the average molar masses of the gases at the center of the sun are about 2.0 g/mol, and their density are about 1.4 g/mL and are under a pressure of 1.3×10^9 atm, what is the approximate temperature? Show all of your work and conversions that you used to arrive at your answer.

Does your answer seem reasonable? Why or why not?

Fermentation is the process of a sugar decomposing to produce carbon dioxide. It is very important for biological processes because of the energy that is produced in doing so. Fermentation can occur when something that has sugar is placed in the presence of an appropriate enzyme, such as yeast. When this happens, carbon dioxide gas, CO_2, is produced.

If a student wanted to study the effect of production of carbon dioxide on by fermenting apple juice, create an experiment that will address this information. What data would need to be collected to allow for the number of moles of gas to be determined?

Use the diagram below to answer the following question.



Assume that the valve between each of the containers is initially closed. If each container has the same number of moles of gas, and the temperature of the entire system is the same, when the valve is opened, would you expect the pressure on the inside of the container increase, decrease or stay the same? Explain your answer.

APPENDIX E

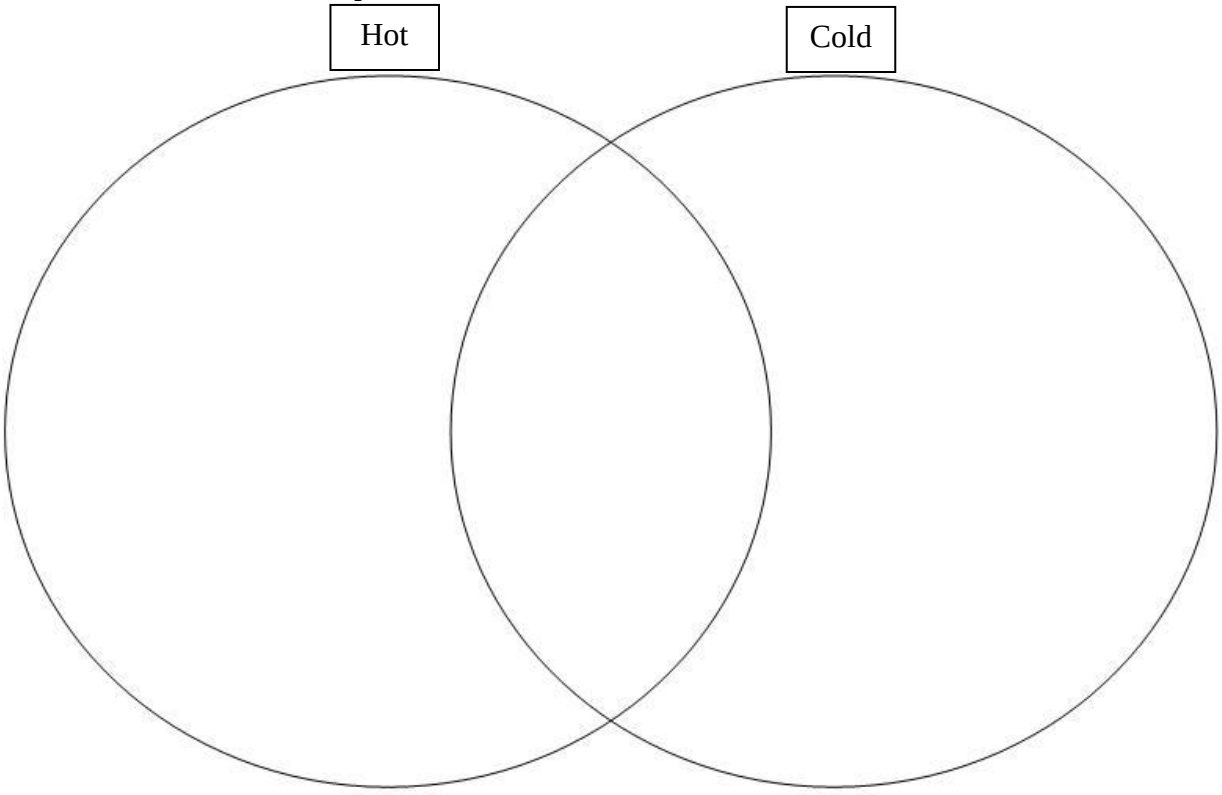
PRE AND POSTUNIT AND DELAYED UNIT ASSESSMENT – TREATMENT UNIT 2

Appendix E

Pre, Post, and Delayed Assessment – Treatment Unit 2

Name: _____

Use the Venn diagram below to indicate the similarities and differences between “hot” and “cold.” Use it to come up with a definition for “heat.”



Heat is :

Equal masses of two different substances absorb the same amount of heat. Substance A has its temperature increase by 5 ^{o}C. Substance B has its temperature increase by 10 ^{o}C. Which substance has the highest specific heat? Explain.

In order to determine which substance, a cracker or a potato chip, contains the most heat, a student lit each on fire. Which measurements would need to be made by the student in order to determine which contains the greatest amount of heat? Explain your answer.

What would be the potential errors for the student from the experiment described above?

The combustion of natural gas, methane is an exothermic reaction that follows the following equation:

$$CH_4(g) + O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \qquad \Delta H = -802kJ$$

The combustion of ethanol, an additive to gasoline, is an exothermic reaction that follows the following equation:

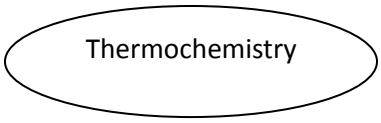
$$C_2H_5OH(g) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g) \qquad \Delta H = -1235kJ$$

If 25 kg of each of the gases were burned, which one would produce the most energy for heating?

A cold pack involves a chemical reaction which simulates ice for an injury that an athlete may sustain. It involves cracking a pellet on the inside of a bag and mixing the chemicals.

Explain how a disposable cold pack works and how it involves heat changes to treat an athlete's injury.

Create a concept map involving the following terms*: thermochemistry, thermochemical reaction, heat, cold, energy, specific heat capacity, joule, calorie.* I have stared the map for you below. You may include extra terms.



APPENDIX F
PRE AND POSTUNIT INTERVIEW QUESTIONS

Appendix F
Preunit and Postunit Interview Questions

1. This unit is called _____ and the main learning objective of this unit is to _____. What does this mean to you regarding chemistry going into this unit?

   Note: I will fill in the blanks above for the students to introduce the interview. The students will not know they are blanks when the interview is given.

2. Does this unit and the learning objectives for this unit seem as though it is going to require you to use a lot of higher level thinking? (Tense change for postunit interview)

3. Why do you believe you answered the way that you did (to question 2)? Explain.

4. What are some specific things that I can do to help you to get through this unit best? How can I help you to use higher order thinking strategies? (Tense change for postunit interview)

5a. Based on the little information that you know about this unit, what type of things do you believe are going to be the most tricky as you work your way through this unit? Why? (Preunit interview)

5b. Based on what you know now about the unit, what was the trickiest thing to you as you worked your way through this unit? Why? (Postunit interview)

6. How do you think this unit relates to our world? Explain.

7. Do you think you will be successful in this unit? (Tense change for postunit interview)

8. Why do you believe that?

9. On a scale of 1 to 10, 1 being the least confident and 10 being the most confident, how successful do you believe you will be in completing this unit? (Tense change for post-unit interview)

10. Nontreatment Concept Question: How do the parts of solutions affect the concentrations of those solutions?

    Treatment I Concept Question: Explain the kinetic molecular theory and why it is important to relate it to gases?

    Treatment II Concept Question: Why is it scientifically incorrect to use the terms “hot” and “cold” when we are describing conditions, such as the weather or temperature of the room?

10. Do you feel like this is a unit that I can structure well to help you to learn the information best? Why do you think that?

11. In what ways do you believe I can make this unit fun for both you and me as we work through it together?

12. Do you believe this is a unit that is enjoyable to teach? What made you think that?

13. Are there any other questions that I should ask? Please ask and answer it.

APPENDIX G
STUDENT SURVEY

Appendix E
Student Survey

Survey Questions:		Strongly Disagree				Strongly Agree
1.	I feel like I understand the main learning objectives from this unit.	1	2	3	4	5
2.	I have a good understanding of how the main objectives for this unit are important to the current unit that we are studying in class.	1	2	3	4	5
3.	My understanding from this unit has helped me to appreciate chemistry in the world.	1	2	3	4	5
4.	I feel like the questions that required me to use the information I learned in this class helped me to understand chemistry better.	1	2	3	4	5
5.	I feel like my teacher planned, executed and taught this unit well.	1	2	3	4	5
6.	I feel like my teacher constant considered my using higher order thinking strategies during this unit	1	2	3	4	5

Please answer the following two questions. Use two pieces of evidence or data from the unit in your answer to support your opinion. Please remember, there are no correct answers and this survey is anonymous.

1. What was the most important thing that you understand from this unit? Please explain why in two or three sentences.

   How does it help you to connect chemistry to other areas of your life? Please explain why in two or three sentences.

2. What stood out to you as the most profound thing that I did as your teacher in this unit? Why do you believe this is?

3. Do you feel like you became a better higher level thinker of chemistry as a result of learning in this unit? Explain.

APPENDIX H

STUDENT REFLECTIVE JOURNAL ENTRY PROMPTS

Appendix H

Student Reflective Journal Prompts

1. Yesterday you learned about _____. Explain if and why this is important to you.

2. What was the most challenging part about your recent learning and why was it the most challenging for you?

3. With all of the difficult learning that we are doing in chemistry now, how do you feel you are doing in learning the concepts and how do you feel the lessons that are being done are helping you to understand them?

4. Concept maps help you to visualize your thinking. How are you using the concept map idea to better learn chemistry?

5. If there was one concept from this unit that you could teach to a middle school student who has not taken chemistry, what would it be? Why did you choose the concept that you chose?

APPENDIX I

TEACHER JOURNAL PROMPTS

Appendix I

Teacher Journal Prompts

1. What was the connection between what my students did today, their lives and my life? Did I implement a lesson today to help them to understand that chemistry is important and did I help them to learn the concepts that they needed to gain that appreciation?

2. What are the best three things that happened in today's lesson? Why were those things "the best?"What are the three things that I should revisit or change before I complete this lesson again? How could I make those changes?

3. How do I feel about teaching with HOCS? Is this something that I feel like I am fully vested in, or is it too forced? How can I make sure it doesn't come forced?

4. What were some things that my students said today that made me take pause? Why did they make me react the way that they did?

5. What evidence do I have that my students are learning with this intervention? If I do not have evidence, what can I make sure I am doing to have evidence?

6. Would today's lesson be one that I would feel comfortable sharing with my department chairperson, principal or parent of one of my students? Would any of the stakeholders of my project be able to recognize the learning that is taking place?

APPENDIX J

TIMELINE FOR PROJECT IMPLEMENTATION

Appendix J

Timeline for Project Implementation

December 1, 2011	Inform parents and students of capstone project and send letter home.
December 6, 2010	Nontreatment Unit Pretest; preunit interviews
December 6-December 13, 2010	Nontreatment Unit Implemented
December 13, 2010	Nontreatment Unit Summative Assessment; postunit interviews; Pretreatment Survey
December 14, 2010	Treatment Unit I Pretest; preunit concept interviews
December 14-December 21, 2010	Treatment Unit I Implementation
December 22	Treatment Unit I Postunit-Assessment; postunit interviews; Nontreatment Delayed Assessment
December 24, 2010-January 2, 2011	Winter Recess – NO SCHOOL
January 3, 2011	Treatment Unit II Pretest and Nontreatment Delayed Assessment; interviews
January 3-January11, 2011	Treatment Unit II Implementation
January 12	Treatment Unit II Summative Assessment and Treatment Unit I Delayed Assessment
January 26, 2011	Treatment II Delayed Assessment