Improving Conceptual Understanding of Chemistry Topics by Guided Inquiry-Based, Hands-On Activities.

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Abstract

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Introduction

As a science teacher a goal has been to provide students with knowledge of science as well as enjoy the experience. To determine if this goal was being met students in all of the high school science classes completed a survey (see Appendix A). A common response over the past six years was that laboratory experiments did not apply to the lecture material. More specifically, the majority of students did not feel the lab exercises were helpful. That is not to be confused with the fact that they liked the labs and enjoyed doing them. From the teacher standpoint, having students relate that approximately 30% of their class time was thought to be irrelevant was disturbing. Also, understanding that the educational push was to promote more laboratory time it was important to determine how to make the laboratory experience a enjoyable time as well as academically helpful (National Research Council, 1996).

From my experience, most of the laboratory experiments are designed as recipe style and are used to familiarize students with different laboratory technique as well as introduce them to laboratory equipment. The problem with recipe style labs is that if students follow all of the steps correctly they could successfully complete the lab and not have any understanding of the science concepts behind the experiment. This idea brought about the concept for this research. The transformation of the recipe labs to guided inquiry-based, hands-on activities would allow students to use their critical thinking skills and conceptual understanding to determine the process they would need to complete the activity successfully thereby reinforcing the lecture concepts. Also used in this research were “Foam Atom Models” that would provide hands-on activities for several topics that do not have laboratory experiments to reinforce the concepts (Dr. Lynn Melton, University of Texas at Dallas).

Because part of most science teachers' goal is to make science "fun" it was also important to determine if the new way of performing laboratory activities would maintain the enjoyment of the science experience for the students. Therefore, students also took a modified Test of Science-Related Attitudes (TOSRA) to assess if two of the five scales, "Attitude to Scientific Inquiry" and "Enjoyment of Science Lessons", was maintained (Fraser, 1978; Ledbeter & Nix, 2002).

The purpose of this study is to determine whether manipulation of the teaching tool of guided, inquiry-based hands-on activities will help to solidify the chemistry concepts and, in turn, elevate the test scores and increase retention time. Data should provide sufficient information to determine if utilizing the student's individual learning style through guided, inquiry-based hands-on activities will prove beneficial allowing a complete understanding of chemistry concepts.

Literature Review

Students appear to lack the ability to connect among topics and concepts in chemistry (Mastropieri & Scruggs, 1994), as well as among all the sciences. Because of this situation, there has been a push for science educators to reform their science teaching by introducing more laboratory exercises to help stem this decline (National Research Council, 1996; Plourde & Klemm, 2004; Luera, Killu, O'Hagan, 2003). Hands-on activities have been presented as a means for teaching science, but these exercises generally follow a step-by-step instruction instead of the inquiry-based hands-on lessons (Huber, 2001). Using canned recipe style exercises limits the way in which a student can learn the material. It does not allow for alternative learning styles of the individual student. Using the Predict, Observe, Explain (POE) method (Palmer, 1997) to incorporate guided, inquiry-based hands-on science promotes individual learning styles and should prove to be a benefit to the student (Gutierrez, 1995).

Concept mapping is regarded as highly effective in assessing the understanding of conceptual material (Stoddart, Arbrams, Gasper, & Canaday, 2000; Van Zele, Lenaerts, & Wieme 2004). The map provides a way for the student to visually show their understanding of the information being presented. Because each student is an individual there will be many variations of maps that are created covering the same topic. The ability and ease of scoring these maps successfully has been the topic of several research studies (Rye & Rubba, 2002; Freeman & Jessup, (2004). To simplify the scoring dilemma, this study compared the number of topics to the number of connections made between topics. A pre-concept map was created before any material was presented and then a post-concept map was made by either updating the original map or by creating an entirely new map.

Also important is the attitude of the students as they are learning science. It has been shown that students will put more effort forth if they enjoy the subject (Wood, ???). Along with that question, is a concern that the Hawthorne Effect, which states that students will perform better knowing that they are part of a research group (Hawthorne, ????) will have an impact on the results.

Methods Section

This research investigated how allowing students to utilize their individual learning styles impacted their understanding of the conceptual material. Also studied was how requiring their thought input, using guided inquiry-based hands-on activities, would impact the understanding and retention of conceptual information. The setting for this research was an urban, college preparatory private school that accepts students within the upper 50th percentile from standardized testing. The curriculum contains both general and honors classes and maintains approximately 18 students per class.

The sample group compares two junior classes for the academic years 2004-2005 (n_1 = 76) and 2005-2006 (n_2 = 48). Table 1 shows the comparison of the classroom populations between the two years. The majority of these students have taken biology and physics, along with Algebra 1 and Geometry; they are currently enrolled in either Algebra 2 or Pre-Calculus. The junior class was chosen because the students are required to complete the same curriculum each year, which would allow the 2004-2005 class to be used as the control group and the 2005-2006 class as the research group. The two groups were verified to be similar by calculating a t-test for independent samples using their PSAT test scores (Gay 1987). See Appendix B for PSAT data.

Table 1

Enrollment Comparison

Year	Number of Students		General Chemistry		Honors Chemistry	
	Female	Male	Female	Male	Female	Male
2004-2005	36	40	27	36	9	4
2005-2006	27	21	19	19	8	2

Each chemistry student also completed the TOSRA[1] as a pre-test/post-test design to determine whether there was a significant change in two of the scales 1) Attitude to Scientific

[1] The pre- and post- modified TOSRA tests contain identical context and therefore do not require any distinction.

Inquiry and 2) Enjoyment of Science Lessons (Fraser 1978). The research was conducted throughout the first semester during which time the general class covered six chapters and the honors class completed nine chapters. See Appendix C for the complete semester Scope and Sequence.

In the past, it is my observation that students typically approach the laboratory experience as strictly a grade and not applied it to the understanding of the material presented during lectures. The purpose of the guided, inquiry-based hands-on activities was to help connect the laboratory exercises with the lectures and thereby increasing their understanding and the ability to retain the concepts being taught.

The foam atom activities were used to help students understand the concept of a granular world and atomic properties without having them get discouraged with the algebra. The concept of a "granular world" was explored utilizing the "Foam Atom Model" created by Dr. Lynn Melton from the University of Texas at Dallas. The model was used for several hands-on activities to help students visualize the atomic understanding and to help solidify atomic concepts (personal communication, August-December 2005). Along with these different atom models, a mass spectrometer and atomic force macroscope were created to help students understand how the properties of an element can be discovered without actually seeing the atom. See Appendix C for detailed descriptions of the "Foam Atom Models and activities. Once the students progressed to compounds and chemical equations, the foam atoms were replaced with Tiddly Winks and plastic jumping bin balls to help with the visualization of chemical equations.

Throughout the research timeframe, the 2005-2006 students prepared concept maps to show their progression of understanding. To begin each chapter, these students prepared a pre-concept map covering the topics in that chapter. During the chapter instruction the students performed guided, inquiry-based, hands-on activities that directly related to the chemistry concepts. At the conclusion of the chapter teaching the students would create a post-concept map by either updating their original concept map or preparing an entirely new one. In contrast, the 2004-2005 class went through the curriculum using lecture, worksheets, and standard recipe labs to introduce laboratory skills as well as reinforce the chapter content. At the end of the research timeframe the students completed surveys to answer specific questions concerning their attitudes toward science.

For a complete understanding of the activities and apparatuses used please review Appendix D and E. Appendix D contains the converted recipe style activities while Appendix E contains descriptions, including photos, of the Foam Atom Models (Melton, 2005), as well as the actual activity presented to the students. A brief description of the activities follows.

Guided, Inquiry-Based, Hands-On Activities

1. One of the beginning activities was the Ob-Scertainer (Lab Aids Inc. #100)(Fig. D1). It consists of a closed plastic circle container with different pattern barriers inside and a small marble. The students were to determine the barrier pattern without using their sense of sight. After the students had drawn their initial barrier pattern the teacher presented the twelve pattern possibilities and had students reevaluate their conclusion.
2. A second activity utilized the concept of density (Appendix D). Students were divided into groups of two. Each group was given one of three versions of the density block activity. One version had a block with a known density value and balance given to the students. Another version had a block with a known density value and a ruler. The third version had the students provided both a balance and a ruler but not the density value. With the given information the students were able to measure either the mass or volume of the block and

calculate the missing piece of the density equation. Once the students determined the missing information, they designed and performed an experiment to test their calculated information for accuracy.

3. A mixture separation was a third activity presented to the students (Appendix D). The students were given one class period to design a laboratory procedure to separate four substances using laboratory equipment that was specified in the activity as available. The following class period they were instructed to follow their procedure and to determine the accuracy of their laboratory technique using the percentage error calculation.
4. The final activity was to identify 11 unknown white powders through qualitative analyses (Appendix D). The students were given ten statements that described reactions of compounds with specific chemicals and indicators. From those statements students prepared a logical flowchart to follow to identify the substances.

Foam Atom Model Activities

1. The initial atom activity (Figs. E1-E2) placed one of each of the four "types of atoms" in a black garbage bag. Students were allowed to manipulate the outside of the bag with their hands to discover what was inside, however they were not allowed to open it. Once they had hypothesized about what was contained in the bag they were allowed to place only their hands in the bag and to again describe what was inside. The groups were finally able to look inside to see the atoms and measure other characteristics of the atoms. The students' final conclusion for this activity was a periodic table (Fig. E3) representing the atoms that were in the bag.
2. The second atom model activity was the "Atomic Force Macroscope", which removed both the sense of sight and touch (Figs. E4-E5). Atoms were arranged to form different letters on

the bottom of the macroscope. Students were placed into groups of two and asked to discover what "pattern" was in the box by probing with the rigid foam probe.

3. The third atom activity was to build a mass spectrometer (Figs. E6-E9). The apparatus is similar to a slingshot and allowed the students to shoot the atoms and determine the relative weights of the atoms. The atoms were modified to obtain five atoms with noticeable different weights. Each of the atoms were shot with the spectrometer and the distance traveled recorded.
4. The final foam atom activity was to place several foam atoms in a bag and have the students figure out how many different compounds they could create (Appendix E). These atoms represented groups 1, 2, 16, 17 and 18 of the periodic table. Each bag contained different atom combinations and could make two, three or four compounds.

The final step in the research was to administer a modified TOSRA, Test of Science-Related Attitudes, (Ledbeter & Nix, 2002). The 2005-2006 class was given the test approximately four weeks after having completed all of the activities. The 2004-2005 was given the test as the control group. The scales that were being evaluated individually were Attitude to Science Education and Enjoyment of Science Lessons. Each scale contained five questions and the average for each student used to calculate a t-test to determine if there was a significant change.

Results and Discussion

The basis for this research was to explore whether using guided, inquiry-based hands-on activities would help to connect the laboratory experience with classroom lectures thereby helping with the understanding and retention of concepts. Students created concept maps before and after the chapter, which did show that there was an increase in understanding, however it was not clear that the research activities caused this increase. There was a noticeable increase in problem-solving ability from the beginning to the end, which is related to the activities and the guided, inquiry-based approach. A detailed account of each activity and several student comments provides a glimpse into classroom atmosphere.

The Ob-Scertainer lab challenged the students to start thinking outside of the way labs were normally completed. This lab was the first experience the students had had with an activity that would not allow the use of vision. Several students actually contemplated the consequence of receiving a failing grade if they opened the Ob-Scertainer and looked inside. Most of the students lacked confidence in being able to get the correct answer, which was their main focus, without visibly seeing the pattern. Visual learners showed the most dissatisfaction with this activity. Even after being given 12 choices they still wanted to open the container and see the pattern. Most students needed the 12 patterns as a prompt to confidently determine their Ob-Scertainer pattern. The students were surprised at how much they rely on sight and take it for granted. Students did express their enjoyment over the new lab protocol and thought this was "fun".

The next activity was the density block. The density concept had been presented to the students and all had a very good idea of how to use the equation successfully. However, few truly understood how mass and volume related to density. To help them understand the relationship students were given a block and a piece of measuring equipment, balance or ruler. The balance provided them with the mass of the block or the ruler provided them with size so volume could be calculated. They were also supplied the literature value for the density of their block. Without any other information the students needed to determine what piece of the density information they were missing and calculate that value. Students were then to create an experiment to determine that value experimentally and finally they applied the percent error calculation to find out how accurate they had been. As an example, if the students were given a balance and the density they would need to calculate the volume mathematically. Students would then determine a procedure to test the calculated value, either by water displacement or measuring the size of the block. Once the experiment was completed they could apply the percentage error calculation.

The students found it very difficult to begin this activity because they were not given a step-by-step procedure to follow. They firmly believed that they had been given something they could not complete because there was not enough information. After approximately 20 minutes one group discovered that they really had two out of the three pieces needed and then realized they could work to get the rest. Once that group was successful the others became more determined and realized that it was possible to successfully complete the activity and that the teacher was not out to "get them". The students really liked the ability to design their own lab procedure, then actually perform it and have it work correctly. An additional benefit was that the students realized how important accurate measurement was for the size of the block. If a group got a high percentage error they would be directed to check their measurements; they were amazed at how much a one millimeter error would affect the outcome. Overall this was a very successful hands-on activity in terms of having students recognize a problem and follow through on the problem-solving techniques to arrive at a solution. It was also evident that students were becoming more confident at beginning an activity and being able recognize the initial problem.

The first Foam Atom Activity was Xanadu's Unidentified Substance in a black garbage bag. Again the students showed both excitement and frustration at the fact that they could not use their vision. This activity was directly related to lecture discussions on how scientists can know about the elements without being able to see them. Many students voiced the question "How do they [scientists] know if they can't see it?" This activity allowed the students to progress in steps through no vision to "seeing" with your hands and finally being able to actually open the bag and looking. At least half of the student groups were able to describe the atom accurately at the first step of only feeling the atoms through the black bag. All of the groups were able to describe the atoms once they were able to feel them. After all of the students had opened their bag they continued to collect information about the individual atoms, such as mass, magnetic properties, size and density. Three student groups made the connection about the Velcro ends being analogous to the bonding properties of atoms.

The students were then to take the atomic data obtained and create an organized format that represented the atoms. This proved to be difficult and frustrating for them because they could not make the connections of similarities and differences well enough to place them in a logical table. The students were guided through connecting the similarities and differences into a format similar to the periodic table. Once they were pointed in the right direction approximately 75% could finish the table accurately with 25% creating tables in a line or an "L" shape instead of a square. During the creation of the table, the excitement level diminished considerably as students had to analyze the data instead of just being told how to organize it. Many students had comments similar to "My brain hurts." and "I don't get it." Once the still struggling students were given the information about the exact layout of the table, several students asked, "Why didn't you just tell us that? It would have been much easier." My response to this was easy, "Because I wanted you to use your brain."

The next activity the students were presented with was an Atomic Force Macroscope. There were ten macroscopes, each with a different letter spelling out the word HOMECOMING.

Obviously this activity was done during the week of our homecoming football game which the students thought was a fun way to tie in learning with sports. The macroscope construction did not allow the students to look inside the macroscope and it was mistakenly thought that students would not try to feel the pattern with their hands. It was discovered very quickly that some students had felt the bottom of the macroscopes with their hands so the macroscopes were rotated among the groups and the rule added that you couldn't touch the bottom with your hands. It took several minutes for students to figure out a way to discover the pattern by only using the probe. Several students were able to see the necessity of working through the pattern with some type of logical order while others approached it from a very hit or miss angle. Students were aware that there was a pattern on the bottom of the box but were unaware that the pattern resembled a letter. Students drew their pattern on the board once they were confident of what it was.

A problem encountered was that a few exuberant students knocked the atoms out of alignment and when they drew their pattern on the board the letter was unrecognizable. As the activity progressed students who were struggling received more clues as to the type of pattern once they started to see the other groups place their letters on the board. It continued to become easier as more letters were discovered and some students started to speculate that all the letters actually spelled a real word. An impromptu game similar to hangman allowed the remaining students to discover their letter without actually "feeling" the pattern. The students did come away with the concept that you can "see" or discover things without actually being physically able to see or feel the item. For the next school year this will be the first activity I have the students work with because it answers the question of "How do they [scientists] know that if they can't see it?"

Another recipe lab converted to hands-on was a mixture separation. Iron filings, zinc pellets, sand, and salt were all placed in a mixture in five-gram quantities. The students were directed to create a procedure that would allow these four materials to be separated using only a magnet, water, screen filter, funnel, filter paper, and a hotplate. They could also use any glassware that would normally be available in a standard lab. They also understood that the final conclusion would be a percentage error calculation to determine the separation success. For one class period they wrote the procedure and the next class period that performed their procedure and determined their accuracy. It was interesting to hear the discussions amongst the students as to the order that the items should be separated and if it would truly make a difference to the final results. All groups successfully separated the mixture however those that separated the metals first had a smaller percentage error than those that poured water into the mixture as the first step. All of the students had the understanding that the different properties of the materials would be used to separate them however they did struggle with ordering the steps of the separation. This was also a very good lab to help the students understand laboratory procedures and how the activity related to the lecture material on physical properties. The activity was interesting for the students however they did not feel like they had done any chemistry because nothing blew-up or changed.

The next atom model activity was the mass spectrometer, which used five atoms that were created with similar dimensions but different masses. Simply by holding them the students could tell the difference in the mass of the atoms and then could hypothesize about how far each atom would travel when shot with the mass spectrometer. Laboratory technique about repetitive measurements was not addressed until groups had shot all of the atoms once. They were then questioned as to whether they could repeat the results and the students found that if they shot the same atom again it was not the same result. This brought up a discussion about lab technique and accuracy in the initial pullback of the rubber bands to shoot the atom. It took students about 15-20 minutes to find a way to overcome the inaccuracy in shooting technique so that the distances were consistent for a single atom. They hypothesized that the lightest atom would travel the farthest. However, this was not the case. After some discussion and a few prompting questions they understood that there is air resistance even inside of a building with no noticeable air current. This lead into the discussion that even though you cannot see particles in the air they are having an impact on items traveling through them. Again, this reinforced the concepts that the world is granular and that even though particles are so small that they cannot be visibly seen they are still present and having an impact. This activity would be more beneficial if performed when discussing the concept of average atomic mass and how the mass of an atom was discovered. For next year this activity will directly follow the Atomic Force Macroscope. The students did enjoy this activity because though it did not explode they did get to shoot something. There was an unauthorized game to see who could shoot their atom the farthest and the most accurately.

The final converted recipe lab was the qualitative analysis of 11 unknown white powders. The students were given ten statements that described how certain chemicals reacted with the 11 unknowns. The students were guided to create a flow chart they could follow to identify all of the unknowns according to the reactions with specific chemicals or indicators. The students were instructed to conserve substance throughout the flow chart. Initially most of the groups created a chart that had steps independent of each other and wasted substance. They were then guided to start with a property that could separate the substances into two groups and then follow one group through to its conclusion. This activity allowed the students to understand how to form a flowchart that would conserve chemicals and limit the procedural steps. The students really enjoyed this activity. They commented about "actually doing real science" because they could mix the chemicals and actually see the reactions taking place. This also gave them an introduction into chemical reactions and they expressed interest to learn more. This activity was a huge success and was a great lead in into chemical equations. Several students had the comment, "How come chemistry can't always be this fun?"

The last foam atom activity dealt with creating chemical compounds with the atoms. Atoms representing the alkali metals (group 1), alkaline earth metals (group 2), chalcogens (group 16), halogens (group 17) and the noble gases (group 18) were placed into a bag. Each student group received a different combination of atoms that would form two, three, or four compounds. Students were to create all the possible chemical compounds for their bag. This experience was similar to the density lab in that it took awhile for students to get the idea but after one group figured it out then all the other groups seemed to pick up on the procedure and were successful. The noble gases did cause some dilemma but the students finally grasped the idea when questioned about how the atoms represented elemental reactivity and bonding properties. This activity was not received very well. Mostly the comments were " I am so tired of having to think all the time. Can't you just tell us how to do it?" The students were solely focused on Christmas break and did not want to use brainpower.

At this point the activities were proving to be mostly successful independently but the question still remained "Did they connect to the lecture and was it helping with the conceptual understanding?" A cartoon came to mind that showed a dog owner lecturing his dog about a bad behavior. The next frame was a picture of the dog with a bubble showing what he was hearing, which was “blah, blah, blah, blah.” I was still not convinced that the students were hearing the real words and not blah, blah, blah.

To begin the second semester the students were asked to describe how they would explain what the world was made up of to a fifth grader. The majority of the answers were very promising with at least half of the students describing the world as being made of tiny particles called atoms and that those atoms combined to create everything in the world. One student described it as “similar to Lego’s.” Only seven students showed absolutely no ability to explain the concept of the atomic particles and how they are the building blocks. It is not known if those seven students truly did not understand that granular concept or if they were lacking confidence to describe what there understanding was. The fact that the overwhelming majority did have a granular concept and could explain it was positive feedback.

Finally all of the students completed the TOSRA survey to determine if their attitude regarding science had significantly changed with the new guided inquiry-based, hands-on regimen instead of the recipe lab format. The averages were calculated for the related questions and utilized in a t-test for independent samples. There was no significant change in either category: Attitude to Science Inquiry or Enjoyment of Science Lessons. The average score when compared for the two years did show a slight increase for the Attitude to Science Inquiry and a decrease in the Enjoyment of Science Lessons. This is a reasonable result from listening to the students’ complaints about “hurting brains” and preferring to be told the information instead of having to figure out information using problem-solving techniques.

Another assessment tool used for the 2005-2006 students was the pre- and post-concept map for each chapter. Each map was scored by subtracting the total number of concepts from the total number of connections. Using an alpha value of 0.05, the results were subjected to a t-test for dependent samples. Though the maps did not show a significant difference according to the t-test there was a noticeable increase in the number of concepts and connections made between the pre- and post-concept maps. These increases indicate that students were gaining understanding while learning the chapter.

The Hawthorne Effect did not appear to impact the actual activities, however it did impact the concept maps. Students were very cooperative and thoughtful when creating the concept maps for the first few chapters, but then the maps became more of a homework assignment than an exciting research instrument. Also noticed was the boredom factor of producing the concept maps. There were several instances in which the pre-concept map had at least double the number of concepts represented on the post-concept map. It was evident that when the maps were due some students were hurriedly completing them just to get the grade. There were also many comments similar to “When are we going to be done with these maps?” This would also go along with the Hawthorne Effect, which states that students will perform better knowing that they are participating in a research project.

Statistical Results

There were four areas that had a t-test calculated to determine significance. The PSAT score was used to determine if the two study groups were similar (Appendix B). Table 2 shows the average score for the 2004-2005 and 2005-2006 students as well as the t-test probabilities. The data supports that these two groups are equal in terms of ability and will provide a good comparison.

Table 2

PSAT Test Scores

	General	Honors

	2004-2005	2005-2006	2004-2005	2005-2006
Average Score	151.98	152.05	182.00	187.67
T-test probability		0.987		0.468

The chapter test results from compared to determine if the test scores were significantly impacted (See Appendix F). Table 3 shows the general chemistry chapter test score averages along with the t-test probabilities. When the t-test was applied to the general chemistry individual tests, chapters 4 and 5 showed that there was only a 1.6%-7% chance that the fluctuations in averages could be solely due to chance. However, when the averages of all six chapter tests plus the midterm were subjected to the t-test it showed that there was a 40.6% probability that the change occurred by chance. Also shown on Table 3 is the honors chemistry test averages and overall t-test probability. For honors chemistry, tests 2, 4, and 5 calculated a t-test probability of 2.6%, 6.2% and 2.8 %, respectively. This correlates with the marked decrease in the test average from 2004-2005 to 2005-2006. When calculating the t-test for the averages of all the tests and midterm combined there was a 7.1% that the change occurred because of something different in the teaching and not strictly by chance.

Table 3

Chapter Test Score Averages

	General Chemistry				Honors Chemistry			
	Year					Year		
Chapter	2004-2005		2005-2006		Chapter	2004-2005		2004-2005

1	79.46		76.01		1&2	82.00		80.20
2	71.41		75.89		3&4	91.69		84.50
3	69.24		71.08		5&10	75.54		76.83
4	63.22		71.50		11	82.85		76.70
5	71.09		77.42		6&7	83.08		71.20
6	71.65		68.89		—	—		—
Midterm	71.11		69.93		Midterm	82.85		74.50
Overall Average	71.03		72.94			83.00		77.32
T-test			0.4062					0.0714

The concept maps were used to determine if conceptual understanding had significantly increased over the course of teaching the chapter. The honors chemistry students' concept maps did show that the change from pre-concept to post-concept was significant and not due to chance with a t-test probability of 2.0%. This change was also evidenced in the rise in the average for the difference between the concepts and connections on the pre-concept map to the difference in concepts and connections on the post-concept map as shown in Table 4. Appendix H contains all of the data for the honors chemistry concept maps while Appendix I contains all of the data for the general chemistry class.

Table 4							
Concept Map Scoring							
	Pre-Concept Map				Post-Concept Map		

Class	Circles (Concepts)	Lines (Connections	Difference		Circles (Concepts)	Lines (Connections)	Difference
Honors	17.55	18.14	1.585		19.65	21.46	2.815
T-test Probability			0.02001				
General	18.41	18.65	1.240		20.68	21.31	1.629
T-test Probability			0.1650				

The final statistical assessment was on the TOSRA to determine if science-related attitude had changed significantly. See Appendix K for the actual test and scoring rubric and Appendix J for complete results. The Attitude to Science Inquiry scale had a rise in average score from 3.212 to 3.591 which when applied to a t-test for a dependent sample the probability was less the 1%. This correlates with the student comments about liking the more hands-on approach. The Enjoyment of Science Lesson also showed a significant change however in the opposite direction. The average score decreased from 3.453 to 3.083 with a t-test probability of 1.0 %. This is also a logical result as the students were frustrated with the inquiry-based problem solving that they were required to do and may not have enjoyed the lesson as much as with the recipe lab activities. Table 5 shows the average data for the TOSRA scales.

Table 5		
TOSRA Scale Results		
	Average Score	
Scale	2004-2005	2005-2006
Attitude to Science Inquiry	3.212	3.591

T-test probability		0.9%
Enjoyment of Science Lessons	3.453	3.083
T-test probability		1.0%

Conclusion

For several years science classes at this private academy have been given a rudimentary survey at the end of the school year in an attempt to improve the science curriculum. One of the questions asked is "How did the labs benefit you?" The overwhelming response has been that the students did not understand how the labs applied to what was being lectured in the classroom. Quite a bit of published research shows that hands-on learning is the preferred style of most classrooms. This research was an attempt to find if guided, inquiry-based, hands-on activities would benefit the students by connecting the activities to the lectures thereby increasing their understanding and retention of fundamental concepts. The students did show an initial excitement for a different way of doing labs. However when they realized that it would require more thought they were not as enthusiastic.

A challenge faced during this research was the conversion of the recipe labs to the guided, inquiry-based hands-on activities as well as the creation of the foam atom model activities. The purpose of guided, inquiry-based, hands-on activities is to force the students to think as much as possible during the activity. It was difficult to anticipate how much information would be necessary for the activity to be successful and how much would be too much thus defeating the purpose. The activities created leaned on the side of too little information, which forced the students to ask questions before they could get started. This research has shown that is it important to spend adequate time preparing the activities to create a better learning environment and less initial confusion for the students. Some information is available on how others have transformed their own curriculum, but is very specific to their individual classrooms (Gallaher-Bolos & Smithenry, 2004).

There were definite benefits that were evident as a result of this research. The students expanded their critical thinking skills by having to work through the activities mentally to develop their procedure and to meet the objectives. Many commented about their “brains hurt” because they were having to “think so much”; however, as the semester progressed it took less time getting into an activity because the students were beginning to utilize more efficient problem-solving techniques. Also, though the t-tests did not show a significant change it is also noted that the test scores did not show a negative significant change either.

Visualizing reformed science classrooms is often easier than actually implementing the changes. Teachers must be willing to apply themselves and to put in additional time for preparation for the inquiry-based science classroom to be successful (Maroney, Finson, Beaver, & Jensen, 2003). As a recommendation, these activities should be modified to address the students’ initial confusion and this research then repeated.

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