

THE IMPACT OF PRACTICAL APPLICATIONS ON STUDENTS' MASTERY
AND MOTIVATION IN CHEMISTRY

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

In

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2015

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ABSTRACT

Many of my students struggle with the content presented in chemistry and have difficulty staying motivated. In addition, there are many negative perceptions about chemistry that have been passed down from other teachers, parents and peers. As an Expeditionary Learning school students are presented with practical applications in order to master content targets in all subjects. In this study I investigated the use of practical applications in the chemistry classroom to determine if it had an impact on student content mastery/retention, student motivation and teacher motivation.

In the treatment students “adopted” an element that is found in water and researched how the element impacts human health, as well as the basic structure, isotopes and Lewis structure of the element. The students also found the amount of their element in DC water (to try to incorporate a personal connection). Students were required to create an infographic (a graphic containing information) that incorporated all of this information. Finally, students presented their work to a group of experts (scientists, water experts and former chemistry students). Throughout the treatment, class time was split into mini-lessons and work time.

Data collection consisted of pre, post and retention tests, analysis of learning target scores, teacher journaling, observations, student surveys and student interviews. All students completed the surveys, pre, post and retention tests and a select group of students were interviewed. My instructional coach and co-teacher completed observations prior to the treatment and during the treatment.

The results from the study indicate that student content mastery and retention does increase with the use of practical applications. It also showed that teacher motivation increased; however, student motivation did not appear to increase with the use of practical applications. Based on these outcomes I plan to continue to use practical applications in my classroom, but in the future I would like to try to emphasize personal connections between students and the content to ensure that student motivation also increases.

INTRODUCTION AND BACKGROUND

Capital City Public Charter School (CCPCS) is an Expeditionary Learning (EL) school in Washington, DC. EL schools use project-based learning expeditions so that students can investigate a topic through in-depth case studies and create authentic projects related to their investigation. For example, in English and World History students participate in an Injustice Expedition. In the expedition students investigate an injustice, find an advocate that promotes social justice, interview the advocate, make a photo essay about the advocate and then present their essay to a group of photojournalists. As an EL school students are frequently asked to connect content to real-world applications; however, the effectiveness of using practical applications has not been directly measured or executed very well in the high school (HS) science classroom (especially the chemistry classroom). EL schools often focus on the elementary level, but there is little data or expedition materials for the chemistry classroom. This study aimed to analyze the impact of context-based chemistry on student and teacher motivation and content retention. The context of DC's water quality was used to teach several traditional chemistry topics (such as Lewis structures, periodic groups, isotopes, etc.).

Students often come into chemistry with the perception that chemistry is difficult and they are going to struggle. In fact many parents have commented that, "Chemistry was one of the hardest classes I took in high school" (which reinforces this perception). Students also have difficulty retaining a lot of the concepts in chemistry, which then requires re-teaching; this study aimed to see if using practical applications could help increase motivation and retention in order to reduce re-teaching time.

In addition to increasing student motivation the study also looked at the impact on teacher motivation. Teachers often resort to “book work” when the content becomes difficult or frustrating for students, lacking the motivation to make the difficult content more interesting. Context-based chemistry may be more demanding of the teacher due to the preparation required; however, it also allows the teacher to be more creative.

As an Expeditionary Learning (EL) school there are many opportunities to share the results of the study with colleagues. First, there are few EL schools that are for secondary students; most EL schools are designed for elementary schools, so there is little guidance/information on how science teachers should incorporate EL philosophies (especially chemistry). As the only chemistry teacher in my school I will be able to share my study results with the other science teachers as well as chemistry teachers in other EL schools that I have met through conferences, etc. When I went to the EL National Conference in the fall of 2014 many of the secondary science teachers said they do not even do expeditions because of the subject matter they teach, so I’m hoping to show that expeditions are possible and beneficial in the secondary science setting.

Research Questions

In order to evaluate the impact of teaching chemistry through a context-based approach the following research questions were investigated. The primary research question was: How does the use of practical applications taught across several topics impact students mastery of chemistry content?

Sub-Questions:

- How does the use of practical applications impact students’ attitudes toward chemistry?

- How does the use of practical applications impact the teacher's motivation?
- How does the use of practical applications impact students' retention of content?

These questions drove the research, and data was collected regarding each question through student interviews and surveys, pre, post and retention quizzes, observations and teacher journaling.

The support team for my action research project was as follows: Katryna Andrusik (my instructional coach), Haajar Celestin (my co-teacher), Marka Latif (former MSSE graduate/MS science teacher), Amy Washtak (science reader and TA for MSSE Chemistry course), Walter Woolbaugh (project advisor) and Brandon Miller (domestic partner and air quality chemist). All of these people assisted in the revisions, data analysis and formation of my final capstone.

CONCEPTUAL FRAMEWORK

Methodology

Several research studies have looked at the development and design of context-based approaches when teaching chemistry. Bulte and Pilot (2006) looked at five context-based approaches and noted similarities and differences amongst the approaches. They mention that in four out of five of the approaches curriculum was designed using a “need-to-know” principle. In other words, “contexts are the starting point for the approach and structure for each curriculum unit” (Bulte & Pilot, 2006, p. 1095). During the treatment DC water was used as the context to teach chemistry; students were assigned an element to research and each day a mini-lesson was conducted on a new topic, then students had time to research in the second part of class; the mini-lessons focused on the content the

students were researching. Bulte and Pilot emphasize that this is important to prevent an overload of curriculum material (Bulte & Pilot, 2006).

The study also mentions the need for active involvement of students in the learning process. This was demonstrated in the treatment because students “adopted” an element. Students took ownership of an element through the process of researching, presenting, etc. In Bulte and Pilots’ research they suggest that projects encourage student involvement. The element project gave students the opportunity to create their own infographic (a graphic that incorporates information) and share their work with judges that were local scientists and water experts, which also emphasized the practical application of student research.

Of the five approaches mentioned in Bulte and Pilot’s work the *Salters Advanced Chemistry* (2006) approach was the primary focus for this study because it was the most accessible and it is closely related to a secondary science classroom. The Salters Approach gives several proposed outcomes that were used to help design the treatment. Bennett and Lubben (2007) describe these outcomes below:

- to show the ways chemistry is used in the world
- to broaden the appeal of chemistry by showing how it relates to people’s lives
- to broaden the range of teaching and learning activities used
- and to provide a rigorous treatment of chemistry to stimulate and challenge a wider range of students (p. 1003).

The outcomes were used to shape the curriculum designed for the application of DC water. For example, the lessons emphasized how elements are found in water and how

the elements impact human health. Students were also required to research the maximum contaminant level of their element in tap water and the level that was detected in DC water in the 2014 Water Quality Report. This demonstrated the relationship between chemistry and the community.

Bennett, Gräsel, Parchmann, and Waddington's (2012) studied teachers' views on context-based curriculums and they also provided an outline for context-based courses. The three characteristics they identified that were used in the treatment are listed below:

- the use of context and applications of science as the starting point for developing scientific understanding;
- the adoption of a 'student-centered' or 'active learning' approach to teaching; and
- the approach to introducing and developing scientific ideas via a 'spiral curriculum' (p. 1523).

The study by Bennett et al. emphasizes that the context used should be relevant to students' lives. As mentioned previously, students investigated elements in water, specifically elements in DC water. DC water is notorious for having problems such as lead in the water (Rhodan, 2012). The 'active-learning' came from the "adoption" of an element. However, Bennett et al. mentions that 'active-learning' should include, "small-group discussions, group and individual problem-solving tasks, investigations and role-play exercises" (p. 1523). Small group discussions were used when the project was introduced as students looked at specific articles relating to elements in water. Discussions were also used when students learned about periodic groups. In addition, problem-solving skills were needed to calculate the average atomic masses of the elements, and for calculating the number of neutrons in each isotope. The 'spiral

curriculum' is similar to the 'need-to-know' approach mentioned above (Bennett et al., 2012).

Bennett et al. compares two different approaches (one context-based and one conventional approach). In the context-based approach the first unit is called "Chemistry for life" and the curriculum uses case studies to look at important elements in the body (similar to the DC Water expedition conducted). In the Elements in our Water project students were required to research how their element helps/harms the human body (to incorporate some biochemistry) (Bennett et al., 2012).

Several articles discuss the context-based approach but offer little insight into the theory behind the approach. In Bennett and Lubben (2007) it states, "we are not overly concerned about "theory" in the Salters developments, and feel that there considerable advantages to be gained by drawing on a range of theories as appropriate" (p. 1012). However, delving deeper into the research it became apparent that the idea of context-based learning started much earlier than the Salters Approach. In *The School and Society*, John Dewey (1899) describes the importance of making education applicable to the everyday life of the student. "One may be ready to admit that it would be most desirable for the school to be a place in which the child should really live, and get a life-experience in which he should delight and find meaning for its own sake" (p. 53). Obviously, the ideas of student engagement and context-based learning have been around for a long time. John Dewey goes on to describe the need for application based learning and critical thinking (Dewey, 1899).

Another educational theory that pertains closely to the project is the Constructivist Theory. In constructivism students are engaged in learning through collaboration and

critical thinking. Instead of focusing on the topics being taught and memorizing information, constructivism focuses on the process of learning through analysis and critical thinking (Demirci, 2009). In this project students conducted research about their element and had to draw conclusions about the information on their own.

In addition to Dewey's theory and the Constructivist Theory this project was also closely aligned with the Expeditionary Learning Design Principles. The design principles that heavily influenced the project are as follows:

1. The Primacy of Self-Discovery
2. The Having of Wonderful Ideas
3. The Responsibility of Learning
4. Collaboration and Competition
5. Solitude and Reflection (Campell, M., Farrell, G., Kamii, M., Lam, D., Rugen, L., and Udall, D., 1996).

The Elements in our Water project encompassed self-discovery through the research of each student's element. Wonderful ideas were incorporated with the design of the infographic and presentation of the element. Students were responsible for their learning via the research and presentation in which they had to apply the content knowledge to their project. They also took on responsibility for their work because of the expert judges that evaluated their work at the end of the project. Collaboration was present during the entire process as students worked together during class to learn about their elements and revise/edit their work. In addition, a healthy competition was present as students presented their work to judges. Finally, all students participated in a reflection of their work throughout the project and especially at the end of the project.

Data Collection

Several types of data collection and analysis were used in the final project to ensure that qualitative and quantitative data were gathered and considered. Bellochi, King and Ritchie (2007) discuss several types of data collection used in their study of chemistry in context. They used “narrative inquiry” in their comparison of conventional and context-based classrooms. Narrative inquiries were used to compare related experiences in order to, “reinforce practices they value or help transform those practices they identify needing change” (p. 369). Narrative inquiries were used with the students, the co-teacher, the instructional coach and the teacher in the study on practical applications. Bellochi et al. (2007) used a student interview and a teacher recollection of experiences to contribute to the study. In the treatment using DC water, data was collected from student interviews and a teacher journal. Interviews were also conducted with the co-teacher and instructional coach as part of the methodology.

In addition to qualitative data, quantitative data was also collected. Gutwill-Wise (2001) used several types of quantitative data that were adopted in the study. He measured, “students’ performance and attitudes using pre-tests, in-class examinations, posttests, and a problem-solving interview” (p. 686). The pre and posttests were used to demonstrate any change in understanding over the course of the semester; similarly, the pre and post survey were used to demonstrate any change in attitude. The students chosen for the interviews were selected randomly based on SAT scores, gender, ethnicity and major (Gutwill-Wise, 2001). A random number generator was used to choose students for the interviews in the study on practical applications. Each student was assigned a number and students were separated into males and females, then students

were chosen based on the random number generator. In addition, pre, post and retention tests were given to note any changes in content knowledge.

Finally, the capstone project by Robin Henrichs (2013) gave several ideas regarding methodology. In Henrichs' study she used a delayed assessment to evaluate students' retention of content. The delayed assessment was administered 14 days after the post assessment. This was incorporated in the study in order to analyze students' retention of knowledge on atomic structure, isotopes, etc. In addition, Henrichs includes copies of her surveys and peer observations forms in her appendix. Some of the questions she uses on these items were also adopted for the study. For example in her peer observation Henrichs has the observer rank the teacher's attitude/motivation, critical thinking of students, student engagement, positive interaction of student and teacher and classroom atmosphere on a scale of 1-5. In the student survey Henrichs again uses the 1-5 scale along with short-answer questions. Some of these same questions were asked of the observers in the study on practical applications. This project clearly was shaped by several research-based approaches in order to create a treatment that was unique, yet engaging for students.

METHODOLOGY

Demographics

At Capital City Public Charter School (CCPCS) students take chemistry during their 10th grade year. CCPCS consists of students from a wide range of socio-economic backgrounds; 60% of students qualify for free lunch and 17% qualify for reduced lunch. In addition, about 40% of students speak Spanish as well as English. On the Preliminary Scholastic Assessment Test (PSAT) that was administered in October the average math

score for 10th graders was 35 and the average reading score was 36. The Scholastic Reading Inventory (SRI) scores from the beginning of the year ranged from 403-1468. Prior to coming to chemistry students that have attended CCPCS throughout their grade school career would have taken Biology (9th grade), physical science (8th grade) and life science (7th grade). Generally most students have learned the very basic structure of an atom (protons, neutrons, electrons), but they have forgotten/never learned how to calculate the number of each sub-atomic particle.

Although all my chemistry students were subjected to the treatment, I collected data from two of my five classes (B and F period). My B period class consisted of 22 students with 5 honors students, 6 special education students (SPED), and 5 English Language Learners (ELL) students. In addition, 11 of the students were African American, one student was mixed and 10 students were Latino/Latina. There were 13 females and 9 male students. In my F period there were 20 students consisting of 2 honors students, 2 special education students, 12 females and 8 males. There were 15 Latino students, one Asian student, and 4 African Americans. My B period seemed to be more motivated to learn science compared to my F period. F period had a lot of discipline issues over the year and struggled to remain focused. My B period had some similar issues, but was better at remaining on task when asked to do so.

Treatment

The practical application of DC water was first introduced to students at the very beginning of the year; therefore, at the time of the treatment students were already familiar with several topics related to DC water. Prior to the action research study students had already designed water filters using everyday materials (sand, gravel, coffee

filters, etc.), investigated the density of different types of water, looked at unit conversions through problems related to water, and conducted a self-designed study on the taste of bottled vs. tap water. In addition, students reviewed scientific concepts: physical and chemical changes and basic atomic structure. Consequently, students had some background knowledge on elements in water, the water treatment process, and harmful chemicals that could possibly be in the water.

After the pre-treatment data was collected students were then introduced to the “Element Project” and the final infographic they had to design for the Elements in Our Water Symposium (Appendix A). Each student was assigned an element that is found in water to research, and had to create an infographic that was then shared at the Elements in our Water Symposium.

For the element project students first completed the “Element Biography Sheet” (Appendix B) to record their research. Students were given a project overview and rubric for the Element Biography Sheet as well as an example to evaluate together. There was a first draft of the research for self and peer evaluation (Appendix C) and a second draft for teacher feedback. Students then had a chance to turn in a final draft for a higher grade. Each day in class we spent the first 20-25 minutes learning and addressing a new topic via lecture/Powerpoint presentation and guided notes (for example, Bohr models, isotopes and relative abundance, etc.). The second part of class (20-25 minutes) was time allotted to students to work on their research and project. This protocol was used as soon as students were introduced to the project and were assigned an element. Next, students completed three drafts of their infographic (one for peer review and one for teacher review). We started with an introduction on what should be included in an infographic,

how to make an infographic using Piktochart (a free online program), and an example infographic was reviewed (Appendix A). Students were then given multiple days in class to work, but were expected to complete the majority of the work outside of class.

Students also had to include a graph of the isotopes and their relative abundances on their infographic. We did a mini-lesson on this as well (lastly about 25 minutes) and then students were given an opportunity to make their graph in the Piktochart program. The infographic was also revised multiple times with a peer and teacher review. The final draft of the infographic was graded using the rubric in Appendix D. Finally students practiced presenting their infographic to classmates for feedback. If students were missing any parts of the project at any point they were required to fill out a reflection explaining why they did not have the required work and they had to design a plan to get back on track (Appendix E). The entire process took about three complete weeks, then students prepared and presented in the Elements in our Water Project Symposium.

The symposium was the culminating piece to this unit, and students' infographics and presentations on their elements were judged by visiting scientists, water experts and former chemistry students (see judges rubric in Appendix F). The Element Infographic had to include: the isotopes of that element along with a graph illustrating the percentage of each isotope, the atomic structure, the Lewis structure, the history/discovery of the element, and how the element is found in water/how it impacts humans by being in the water. In addition, at the end of the project students completed a reflection, which focused on their motivation throughout the project, suggestions for the future and their ability to retain content knowledge (Appendix G).

Instrumentation

In order to evaluate the effectiveness of the treatment several instruments were used: pre, post, retention test, interviews, surveys, observations, and a teacher journal. To measure content mastery students took a pretest prior to the treatment, a posttest at the very end of the treatment and a retention test three weeks after the unit ended. The pre and retention test were administered using an online quiz (Appendix J). The posttest was paper and pencil and was more specific to what students had learned during the unit (Appendix K). Students final grade on learning targets was also examined based on their scores on the posttest, their final infographic, and scores from the judges.

In addition to the content mastery data collected, there was also data collected on student motivation and interest level. Before the project began students conducted a pre-treatment survey, the same survey was again administered during and after the treatment (Appendix H). Five students were also randomly selected for individual interviews and were interviewed before, during and after the project. In addition, there were observations conducted by the instructional coach and co-teacher using the observation form (Appendix I). The instructional coach is an administrator that assists teachers with instruction through professional development, coaching cycles and observations. She offers constructive criticism to support teacher growth. A teacher journal was also used weekly throughout the treatment to keep notes on how the treatment was proceeding. The combination of instruments used for data collection ensured that data was collected from a variety of audiences for different perspectives on the same work. For example, observations were conducted both by the co-teacher and the instructional coach, and student surveys were given to all students as well as individual interviews. The

instrument matrix below shows the data collection techniques that were used to ensure that limited bias went into the final analysis of results.

Table 1
Instrument Matrix

	Pre-test	Post-Test	Retention-Test	Individual Student Interviews	Student surveys	Co-teacher Observation	Instructional Coach observations	Teacher Journal	Project draft content	Project Rubric Judges' Scores	Project Reflection by Students
How does the use of practical applications taught across several topics impact students mastery of chemistry content?	x	x	x	x	x	x	x	x	x	x	x
How does the use of practical applications impact students' attitudes toward chemistry?				x	x	x	x	x			x
How does the use of practical applications impact the teacher's motivation?				x		x	x	x			x
How does the use of practical applications impact students' retention of chemistry content?	x	x	x	x		x	x	x	x	x	x

The table also notes how each sub-question was answered. Triangulation was used as much as possible to ensure validity and reliability. In addition, my co-teacher assisted in the creation of the pre, post and retention test, the student surveys, project reflection, the judges rubric and the project rubric (for scoring the drafts of the project). My instructional coach assisted with the creation of the observation form. Finally, peers in my master's program and my instructor also gave feedback on each of the instruments

used. The research methodology for this project received an exemption by Montana State University's Institutional Review Board (Appendix N), and compliance for working with human subjects was maintained.

DATA AND ANALYSIS

Multiple types of data were collected and analyzed in order to determine the effectiveness of the treatment. The data was split into three main categories: Student Survey/Interview and Reflections, Co-teacher/Instructional Coach Observation Data, and Pre, Post and Retention test Data. This also aligns with the three sub-questions that were being answered regarding student motivation/interest level, teacher motivation and student content retention/mastery.

Student Survey/Interviews and Reflections

Several types of data were collected in order to determine if student and teacher motivation is impacted by the use of practical applications. Students were first given a survey using Google forms and asked what their most and least favorite activities were so far this year (Appendix H); they were also given the same survey two weeks into the treatment and then after the treatment as well. This allowed for some background information on what students found most interesting and how it changed throughout the treatment. Individual student interviews were also conducted before the treatment, during the treatment and after the treatment. In addition, after the treatment students were given a project reflection to complete.

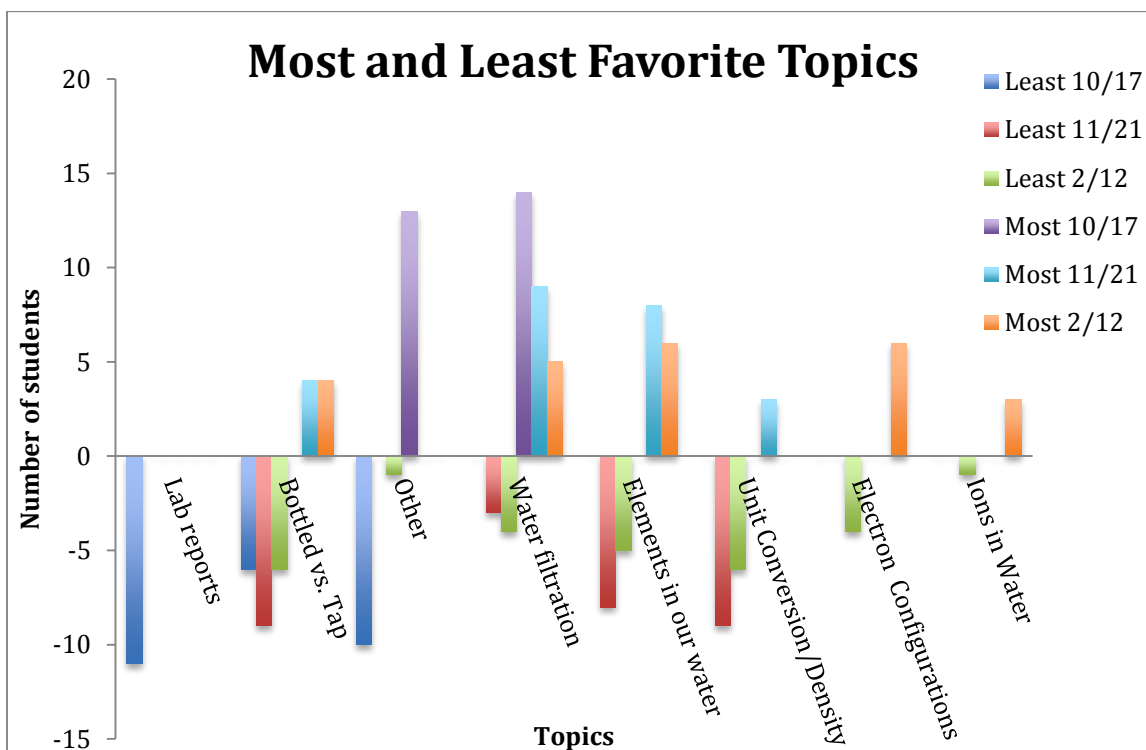


Figure 1. Students' most and least favorite activities as of October 17th, 2014 ($N = 27$), November 21, 2014 ($N=26$) and February 10, 2015 ($N=26$).

In Figure 1 it shows that in the fall students enjoyed the water filtration lab the most (52% of students), which was a hands-on experiment that required students to attempt to filter dirty water. Students were given materials (such as charcoal, sand and gravel) to try to filter the water. When the survey was administered on November 21st students also stated that they enjoyed the Elements in our Water (it was the second most favorite activity at 33% of students). In February students' most favorite activity was the Elements in our Water Project and electron configurations (both at 25% of students). As one student that enjoyed the Elements in our Water Project stated, "I felt more motivated to try harder and the project was something I've never done before so that made it more interesting." In one interview a student stated, "how elements are in our water (was my

favorite) because it's weird how they get inside the water, like natural erosion and people put fluoride in the water." Students may have enjoyed electron configurations because it is a topic that is grasped fairly quickly, but also generally makes students really proud when they do grasp the concept. One student that chose electron configurations said, "It was something easy that I really caught on to and I felt like I got a lot of help with it."

Students' least favorite activity was writing lab reports (10/17 at 41% of students), unit conversions/density and bottled vs. tap lab (11/21 at 31%) and unit conversion/density and the bottled vs. tap lab (2/10 at 27%). This is probably because we spent a lot of time working on revising and perfecting the reports and students struggle with the math involved in unit conversions/density. One student stated, "My least favorite thing were the very tedious and time consuming lab reports." In general it was clear that students enjoy the hands-on activities and labs the most. Many students said their interest level would increase if we did "more exciting labs." In February students conducted an ion flame test and it was mentioned several times that they would enjoy doing more labs like that. It was also interesting that students mentioned the Bottled vs. Tap Water lab, Water Filtration Lab and the Elements in our Water in their most and least favorite activities. All of these activities relate to our practical application of DC water treatment. This may indicate that even if something was a least favorite activity it was at least memorable (and hopefully helping them retain information).

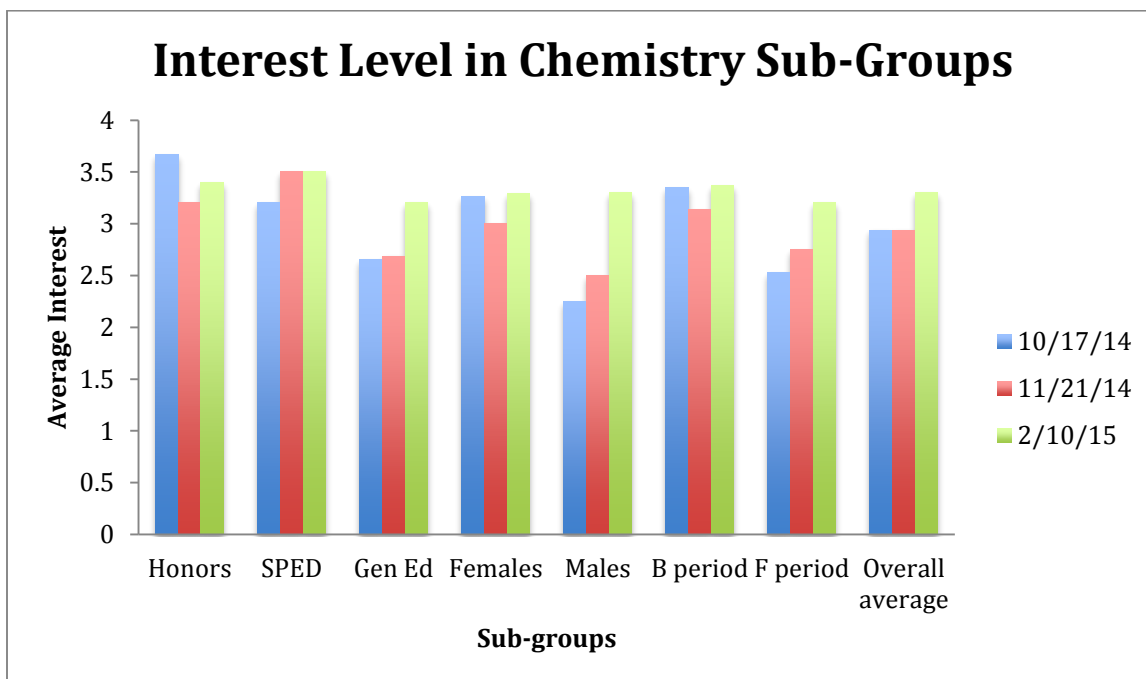


Figure 2. Students' interest level in chemistry as of October 17th, 2014 and November 21st, 2014 using the Likert Scale 1-5 (1 being no interest and 5 being very interested) ($N = 27$ on 10/17/14, $N=26$ on 10/21/14, and $N=26$ on 2/10/15).

Figure 2 shows student interest level (as a measure of motivation) on a scale of 1-5 (1 being no interest and 5 being very interested) as of October 17th, November 21st and February 10th. All sub-groups increased motivation level during the treatment except honors, females and B period; additionally, the overall average was the same for the pretreatment and during treatment. However, in February all sub-groups increased in motivation level. The overall average for both classes was 2.94 during the pre-survey and during-treatment survey and in February the overall average was 3.3. B period's interest level went down between the pre and during treatment, while F period increased in interest level over time; however, overall B period was more interested than F period. This may be a result of my B period being co-taught or the fact that my B period has more honors students (often indicating that students at least have a bit more interest in

science). Honors students and special education students showed the highest interest within my sub-groups, although by February all sub-groups were fairly similar in their interest level. I would expect honors students to be most interested, but it should also be noted that special education (SPED) students were relatively interested even though they often struggle more with the material. Perhaps the support system that SPED students have in place (i.e. modifications and accommodations) allow them to access the information in a way that makes it interesting to them. In addition, the SPED students in B period get extra support from the co-teacher. Females were overall more interested than males as well. However, this may be because there were 19 females surveyed and only 8 males.

Students may have increased their interest level in chemistry in February because we were just starting a new semester and there were many breaks in January. In addition, as the year goes on students often become more motivated to be successful and build a stronger relationship with the teacher, both of which could impact their overall motivation level. Students also recently conducted the flame test when discussing ions, which sparked many students' interest.

Some of the most common reasoning for why students reported their motivation level as they did was as one student stated, "Some topics are just a bit more interesting than others, I think. I'd have to say I feel rather neutral so far." Some of the outliers that indicated very little interest stated, "I answered the way I did because none of the topics have caught my attention. They were non-interesting to me. They were sort of, well, they were boring." These outlier students are generally students who have the ability to grasp concepts, but for one reason or another are unmotivated when it comes to school. They

are frequently absent or have their heads down, but are able to pass because they have fairly strong academic content skills. One of the highly interested students stated, “It's good to know what you are putting into your body and knowing this now I can help me later in life because you always need to drink water.” Again, this relates to our practical application of DC water treatment. The highly interested students (those who consistently ranked their motivation at a 4 or 5) were generally students that do well academically and/or have a close relationship with the teacher.

In February during the interviews students were also asked if using water to teach chemistry concepts was helpful. Seventy one percent of the students surveyed said that using water to teach chemistry concepts has helped them, 17% said it has helped a little bit and 12.5% said it has not helped at all. As one student stated, “I think water is a good base for most chemistry concepts because it is found with nearly everything. Because of this, it can be used for many different activities and lessons. It also maintains a theme for the class I guess.” One of the outliers commented, “Not really because the water did not change my understanding all that much.”

In addition, students were asked several questions on the project reflection about their interest in the Elements in our Water project (Appendix G). Eighty six percent of students said that the project helped them learn. “Yes, because it helped me learn and understand how many isotopes do the element has and the percentage of the isotopes. It also helps me learn about how the element is made and the origin,” stated one student. In addition, 77% of students said they enjoyed the project and 77% of students said we should continue doing the project in future years. Many students commented that they enjoyed making the infographic. For example, “I did enjoy it because making the

infographic, it was fun. I liked designing the infographic.” One of the outlying students commented, “No (I did not enjoy it), because it was difficult for me at times and I would get frustrated on certain things.” Finally, 82% of students said they are proud of their project. As one student commented, “Yes, because even though I struggled I still finished and stayed focus in class most of the time.” Students were also asked what could be changed to improve the project in the future. Many students said they could have used more time to practice the presentation (which is very fair because we definitely had to rush at the end). A few students also commented that not limiting the topic to water would be helpful, or making a poster instead, and many students said nothing should be improved. One student remarked, “Nothing, honestly I thought this project was good.”

Pre, Post, Retention Test and Project Data

In addition to the qualitative data that was collected from the students there was also quantitative data collected. Students were administered a pre, post and retention test to analyze students’ knowledge throughout the treatment. The pre-test and retention-test were administered using Schoology (our school’s venue for homework postings) quizzes; this allowed the data to be easily collected and transferred to Excel (Appendix J). The post-test was a paper and pencil test because it was more specific to what he had covered in class and required some short-answer questions (Appendix K).

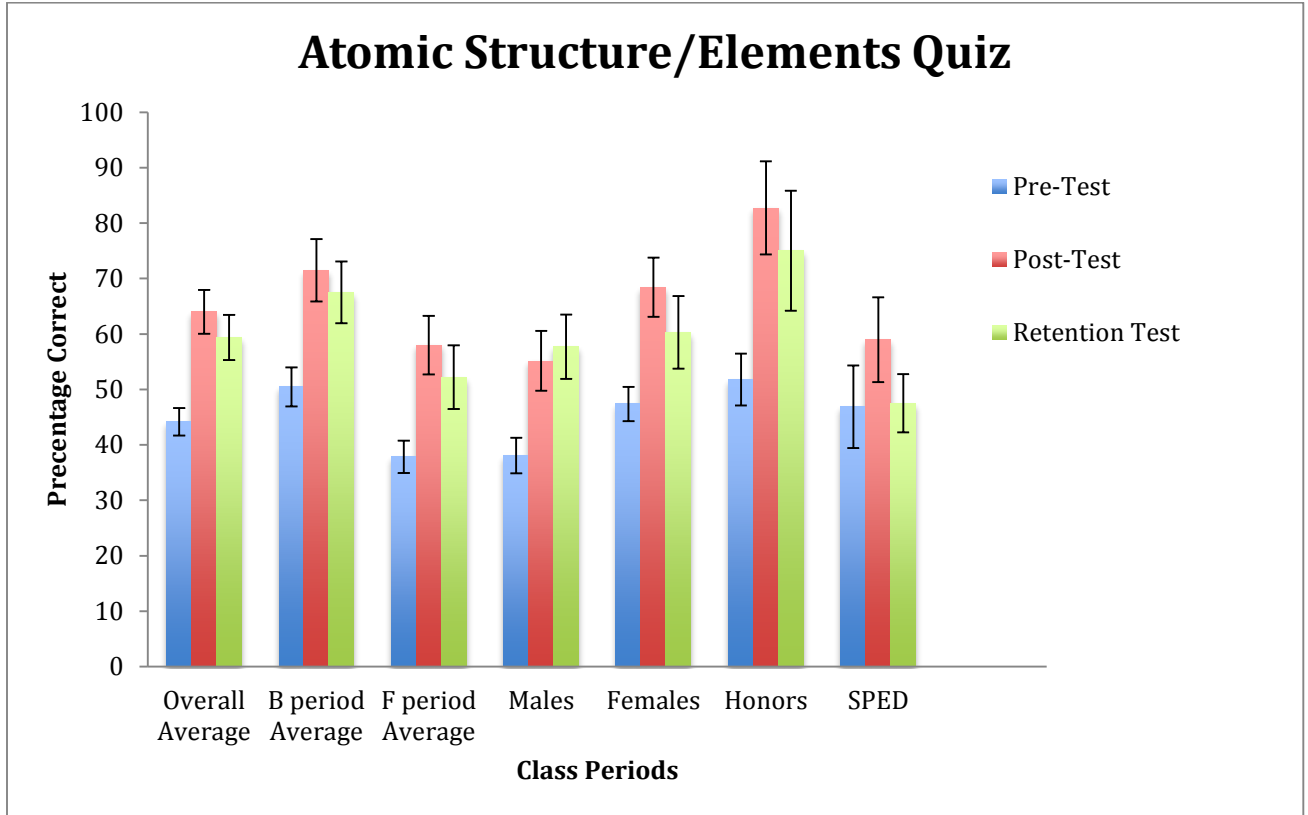


Figure 3. Pre, post and retention test average scores for subgroups with standard errors ($N=32$ on pre-test, $N=36$ on post-test, $N=32$ on retention test).

The overall average for each test indicates that students did better on the posttest than the pretest. Students dropped slightly for the retention test, but still the retention test average was higher than the pretest for all sub-groups. Based on an ANOVA test, all sub-groups show a significant difference ($p < .05$) between the pretest and the posttest except males and SPED (means and standard deviations are in Appendix L). This may be because a few male students appeared to have not tried at all on the pre or posttest (based on their test scores). This also occurred in the SPED subgroup where a few students scored much lower than the rest because they do not come to school on a regular basis and/or complete few assignments. This is also indicated in the standard error bars for those subgroups. There was a significant difference between the pre and retention test for

the overall average and males. This signifies that on average students' knowledge significantly increased from the pre to the retention test.

The two sub-groups with the highest averages were B period and honors. (Again, this is most likely due to the fact that there are more honors students in my B period). In addition, honors students may have scored higher than any other sub-group because of their previous knowledge/interest in science and their desire to learn. F period, males and SPED students scored lowest on average. F period has more male students than B period, so the fact that both averages are low makes sense. Again, SPED students had a wide range of results. Students that scored extremely low on the retention test are students that may have not tried at all; they are generally students that do the bare minimum and when they were told that the test would not impact their grade they may have stopped trying. In the future it may be helpful to not tell students this information in order to ensure that they at least try.

Students were also graded on their Elements in our Water project. They were graded on their 2nd draft, the final infographic, and their presentation (by the guest judges). The scores on each learning target were found along with the median score and first and third quartile (Figure 4). The scores were given using the standards based scale we use at CCPCS, which is 1-4 (1 is not meeting the standard, 2 is approaching the standard, 3 is meeting the standard and 4 is exceeding the standard).

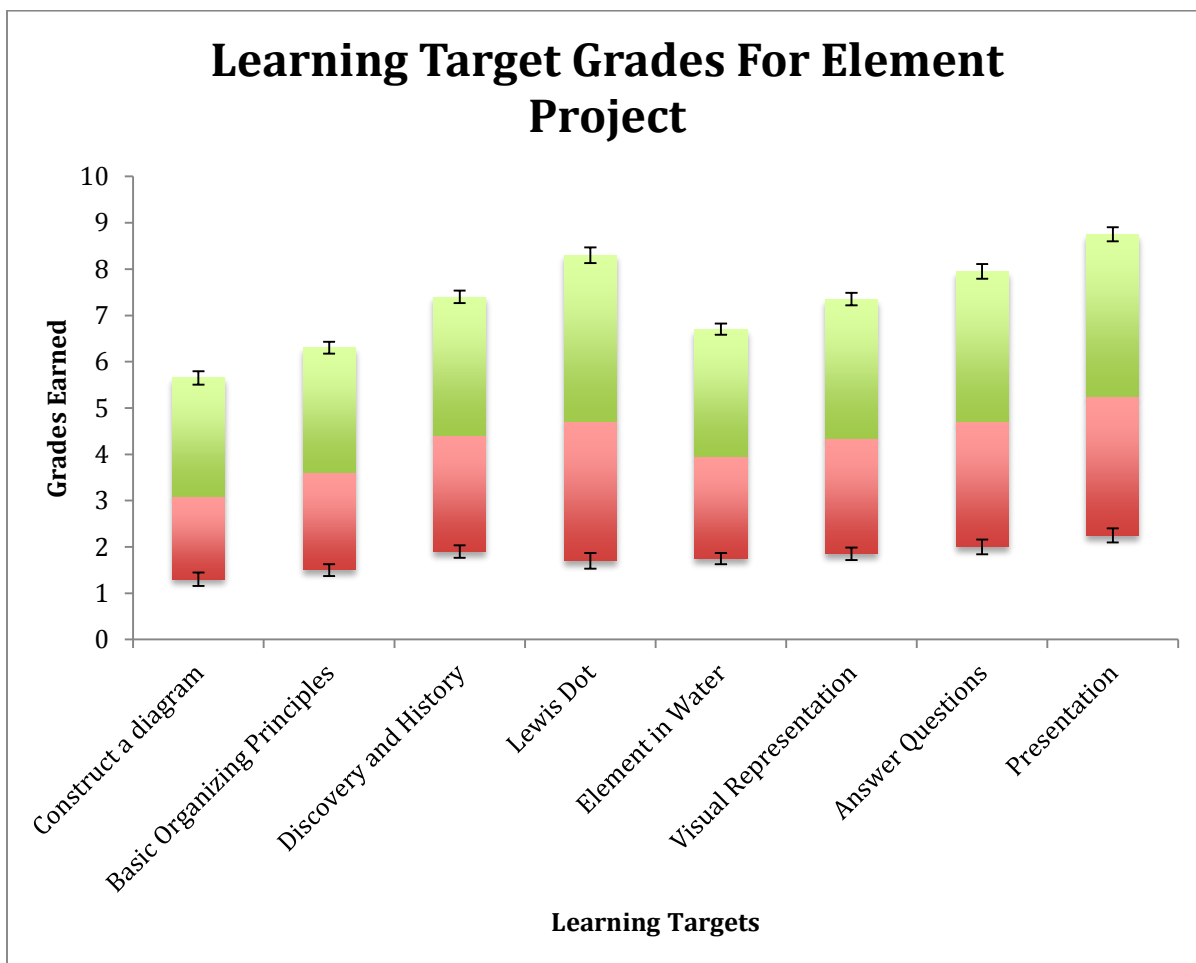


Figure 4. Average learning target grades for the Elements in our Water Project. The median (red) and the 3rd quartile (green) are shown along with standard errors ($N=39$).

Students scored had the highest median score (3 out of 4) on the learning target for drawing the Lewis structure of an element and presentation skills (eye contact, volume, etc.). Students also scored high (2.7 out of 4) on answering questions during the presentation. Drawing the Lewis structures of elements is very straightforward especially when the pattern is followed of using periodic groups to determine valence electrons. In addition, students were presenting in front of an outside audience including scientists and water experts, this made the students nervous but also ensured that students took the

presentation seriously. This may be why students scored the highest on these learning targets.

Overall students scored the lowest on constructing a diagram of the atomic structure (1.8), which included finding the percentage of isotopes and graphing these isotopes. This was probably the lowest because school-wide teachers feel that students consistently struggle with anything related to math especially finding percentages. The other learning targets were all a relatively similar median.

Based on these data results the lessons and instruction significantly impacted the learning of the students. In addition, students performed under the pressure of their expert audience.

Instructional Coach/Co-teacher Data

My instructional coach and co-teacher observation results help answer several of my sub-questions and my guiding question. On the observation form (Appendix I) I asked for feedback on several items related to the use of practical applications. This helped demonstrate that I am in fact using “practical applications” to answer my guiding questions. I also asked about the perceived student and teacher motivation.

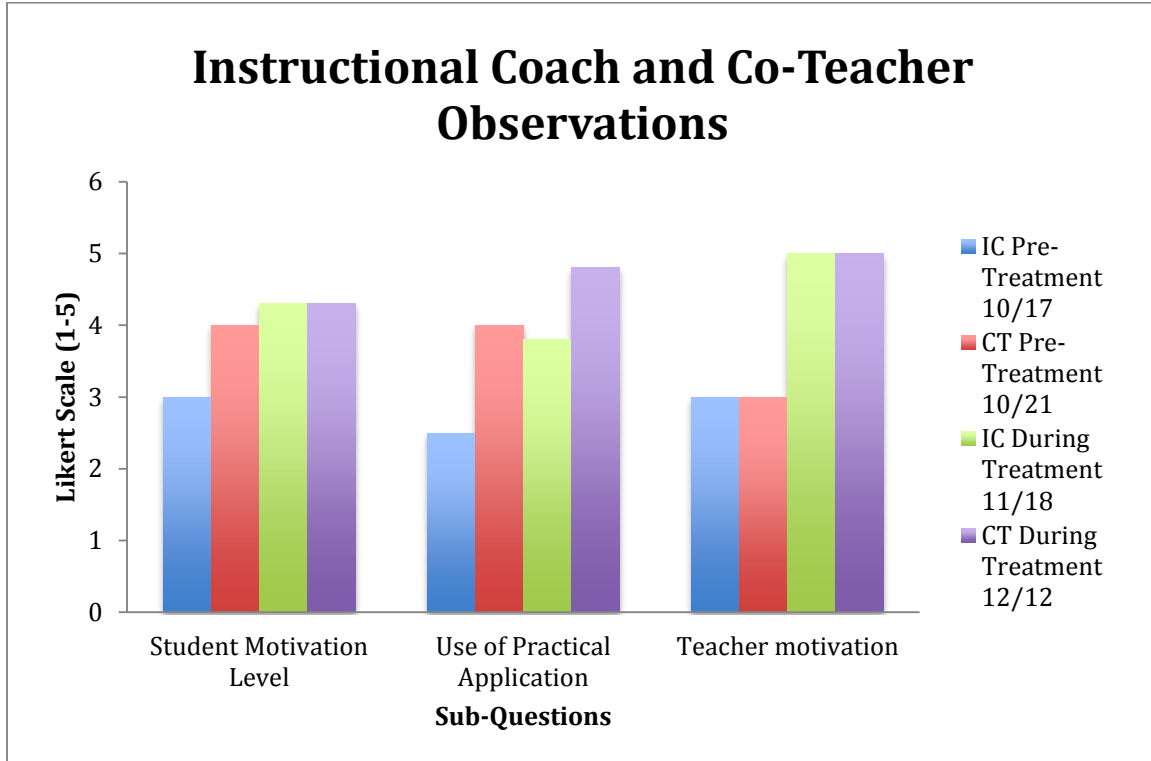


Figure 5. Instructional coach and co-teacher observations of student and teacher motivation before the treatment and during the treatment.

After coding the questions I determined the average Likert score for each major sub-question asked about (Figure 5). They were asked to rate the class from 1-5 (1 being not at all present and 5 being present to a great extent). My instructional coach observed me both before the treatment (10/17) and during the treatment (11/18) and so did my co-teacher on 10/21 and 12/12. In December my co-teacher observed the culminating presentation in which the students presented their final infographics to the judges.

In terms of the use of practical applications, in the first lesson the instructional coach commented that the lesson was math focused and was not explicitly related to other disciplines or a practical application. She stated, “Students didn’t investigate anything although the attitude was that this math mattered.” It should be noted that my instructional coach ranked the use of practical applications at an average of 2.5 in

October, but the average was 3.8 in November. In November she commented, “Students have begun exploring elements/classes of elements. They began making connections beyond just the periodic table.” In October my co-teacher gave me an average of 4 for the use of practical applications; she may have rated this higher because she is actively involved in the planning of the class and is more invested in the curriculum. In December she rated the use of practical applications at a 4.8. Again, this may have been rated higher due to her active role in the preparation of the class or the fact that the day she observed students were solely presenting their work on elements in water.

For student interest/motivation in October my instructional coach stated the motivation level was, “very minimal. All tasks were required and therefore completed as mandated.” On the other hand, my co-teacher commented, “Students were encouraged when feeling like the content was not important. The relevance of the content was continually reinforced.” In November my instructional coach (average of 4.3) said, “The students seemed highly engaged in creating understandings within groups of elements.” My co-teacher also rated student motivation at a 4.3; she stated, “Students were highly motivated to present. Even students who were not “fully” prepared came in asking if they would still have that opportunity.”

In terms of my motivation level in October my instructional coach indicated that motivation was evident based on the fact that I clearly valued the instruction based on my tone, stance and practice. She also stated, “the co-teaching model facilitated motivation and teacher ability to support and facilitate instruction.” My co-teacher stated, “. . . as each new task was introduced, teacher used positive language and a moderate level of enthusiasm.” Both my instructional coach and co-teacher rated me at 3 out of 5 (a neutral

rating). In November my instructional coach rated me at a 5 and commented, “teacher’s overall motivation level seems high.” Likewise, my co-teacher also rated my motivation level at a 5 in December. She commented, “The overall motivation level of the teacher was high. It was evidenced by the preparation, organization and the climate of the symposium.” Although each observer evaluated slightly different, it is clear that teacher motivation increased with the use of practical applications and so did student motivation (although student motivation did not increase as much as teacher motivation).

Overall student motivation has increased over time, but this may not be a result of the treatment according to both students and outside observers. Average student content knowledge and retention increased with the treatment. In addition, teacher motivation increased with the treatment based on observations and teacher journals.

INTERPRETATION AND CONCLUSIONS

Based on the data each of the sub-questions was addressed regarding student motivation/attitude, teacher motivation and student retention. The data suggests that using practical applications does have an impact on students and teachers; however, it is unclear whether practical applications are motivating students or creating more interest in the content.

Students’ attitude towards chemistry (the second sub-question) was evaluated by looking at student motivation. Student motivation increased over the course of the year (Figure 2), but it is unclear if the use of practical applications increased interest level. Students’ most and least favorite activities were a variety of activities; nonetheless, many of the activities identified did relate to the use of practical applications (i.e. Bottled vs. Tap lab, Water Filtration and Elements in our Water, etc.). Even if students did not enjoy

the activities they were at least memorable and this was indicated in their most/least favorite activities. The overall average motivation level of students did not increase with the use of practical applications, but it did increase later in the school year (Figure 2). The practical application of DC water was used throughout the school year, so it was difficult to evaluate motivation level in relation to the practical application. Based on student comments and interviews students seemed to be most motivated when we were doing an “exciting lab” such as the ion flame test (which was unrelated to the practical application).

On the other hand, based on observations (by the instructional coach and co-teacher) student motivation did increase with the use of practical applications (Figure 5). In both observations the observer commented that students seemed more motivated with the application of DC water. This was also indicated in the teacher journal; it appeared that students were more motivated when they were researching/discussing the practical application. The use of a mini-lesson followed by project work time allowed for less frustration and more engagement in their work (based on teacher observations), which may have resulted in increased motivation.

The first sub-question investigated how the use of practical applications impacted content mastery and retention. Students did appear to gain content knowledge through the use of practical applications as indicated by the pre, post and retention test (Figure 3). All sub-groups showed an increase between the pre and post, and pre and retention test; although this growth was not always significant it was still growth. Based on the growth, it can be concluded that the use of practical applications increased content knowledge and helped students retain this knowledge. Based on students’ scores on the Elements in our

Water project and presentation it can be concluded that students also took the presentations very seriously and did well with their presentation skills. Students did fairly well meeting all learning targets (with only one average below a 2.0). The learning target that related to constructing a diagram of the atomic structure was below a 2.0, this included calculating the relative abundance of isotopes, which involves a lot of calculations that students struggled with. The average was above a 2.0 for all other learning targets, with the highest averages related to the presentation of student work (answering questions from the judges, 2.36, and overall presentation, 2.7) and Lewis dot structures (2.6). Based on the rubric and scores this means that on average students were approaching mastery/very close to reaching mastery for all the learning targets. It can therefore be concluded that the use of practical applications assisted students in reaching mastery for the learning targets evaluated during the treatment.

The third sub-question looked at teacher motivation and was evaluated through observations by the instructional coach and co-teacher, and a teacher journal. Based on the observations and teacher journal it was clear that teacher motivation increased with the use of practical applications (from a 3 to a 5). The teacher journal noted that planning using practical applications makes it more interesting because the teacher was able to learn at the same time as the students. For example, I learned how different elements get into water (while the students were also researching). It is also more interesting to plan activities that are not the standard textbook assignments, it allows for creativity and more student-led activities (such as the planning/making of the infographic).

In conclusion, the use of practical applications may not directly correlate to student motivation, but it does appear to help to make the content more memorable for students.

Student mastery of content increased with the use of practical applications and helped students retain the content. In addition, the use of DC Water to teach chemistry increased teacher motivation. Therefore, I will continue to use practical applications when teaching chemistry content.

VALUE

Using practical applications allowed students to connect chemistry to something they are all familiar with (DC Water). It made it more enjoyable for the teacher and increased student mastery. As the year progressed the use of the practical applications was continually used; as the year went on students appeared to become more and more interested (especially when we were able to discuss more difficult concepts like chemical reactions and ions). Many discussions and questions were asked and students were continually engaged in their work. As a final project students collected water samples from their homes and tested them, then used different types of filters to see how well the filters work. Students really enjoyed the personal connection they made by using water from their own homes, thus, in the future I would like to try to make more personal connections earlier in the year. I think this would support the use of the practical application and increase student motivation. Over the next few years I plan to continue to use DC water as a practical application in order to refine the process even more and find more experts/projects for students to complete.

In the future it may be helpful to compare my final results to a study that uses a more traditional curriculum map. It would also be interesting to see if other practical applications (maybe food, city planning, etc.) are more or less interesting to students. Another idea is carrying out the study throughout the entire school year (since I am using

the practical application throughout the school year) this would allow me to see how practical applications impact students all year long (as opposed to the one limited treatment).

Based on the study and as a teacher in an Expeditionary Learning school I plan to continue to use practical applications in my instruction. Students clearly are learning (and remembering) the content better, and if I used more personal connections I believe student motivation would also increase. Students have worked very hard on their projects related to DC water throughout the year and in general they are proud of their work (which was also seen in the treatment). By giving students the opportunity to more deeply learn about a specific topic students become connected to the content. In addition, I am more excited about teaching the content and planning the curriculum when I have a practical application to apply.

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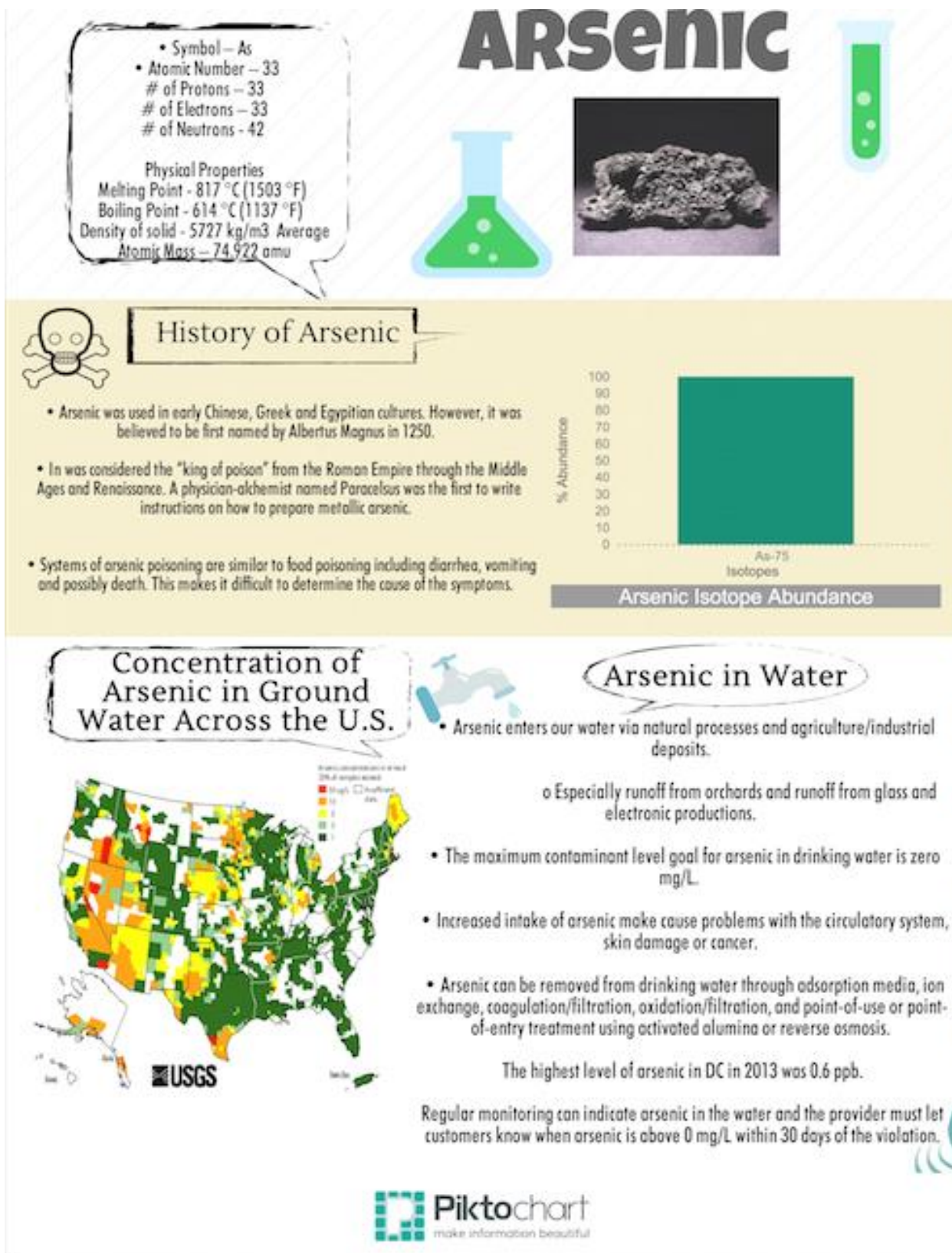
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APPENDICES

APPENDIX A

ELEMENT INFOGRAPHIC EXAMPLE



APPENDIX B

ELEMENT BIOGRAPHY SHEET

Name: _____ Date: _____ Period: _____

Element Biography Sheet

Element Name: _____

Symbol: _____

I. Basic Information

(1) What does the name mean? (What is the origin of the element's name?)

(2) How was the symbol determined?

A. Properties

(3) Look up the physical properties of your element. Record the physical properties below:

Melting point:

Boiling point:

Atomic Weight:

Density:

Phase at room temperature (solid, liquid, gas):

Source: Circle one: Website Textbook News article

Name of source:

(4) Where is your element found on the periodic table?

Group: _____ Period: _____

(5) Does the Group have a name? What is it? (*for example, elements in group 1 are called Alkali Metals*)?

(6) What are the properties of this group of elements?

Source: Circle one: Website Textbook News article

Name of source:

B. Subatomic Particles

(7) Find information on Isotope abundance:

a. What are the stable isotopes of this element

Isotope	Natural Abundance (atom %)	Number of Neutrons

NOTE: There may be many more or many fewer isotopes than there are spaces here. Please add rows if necessary.

(8) What is the most abundant isotope?

(9) Use the atomic number and the most abundant isotope to calculate the following information:

Particle	Number
Protons	
Electrons	
Neutrons	

Source: Circle one: Website Textbook News article

Name of source:

II. History

**** If your element was synthesized, include information about when it was first made****

*** If your element has been known since “ancient times,” there will be no “discoverer.”***

(10) When was the element discovered?

(11) How was the element discovered/synthesized?

(12) Who discovered the element?

Source: Circle one: Website Textbook

News article

Name of source:

Element in Water (THIS IS YOUR MOST IMPORTANT SECTION)

(13) Since we are discussing water this semester how is your element found in water (is it in a compound, element or ion form – list all ways your element is found in water)?

(14) How does it get into the water? Is it naturally occurring, a pollutant, etc.? (Be as specific and detailed as possible).

(15) Is it harmful to humans or other organisms when it is present in water? Is there a Maximum Contaminant Level? If so, what is it?

(16) Are there any ways to remove it from the water or prevent it from entering the water? If so, explain how.

(17) How is your element detected in the water? (What types of tests can be used to detect it?)

(18) How much of your element was found in DC water last year? (List the highest amount and the range). Does this fall within the EPA limits?

(19) Describe any other interesting information you found about your element in water. (Examples may include who to contact if you suspect having too much of the element in your water, etc.).

Source: Circle one: WebsiteTextbook News article

Name of source:

Wrap- Up

(20) What is this element “known for”? Give three cool facts.

(21) In the space below, answer the following questions: *Why is your element important? What should your classmates know about your element especially as it relates to water?*

Source: Circle one: WebsiteTextbook News article

Name of source:

APPENDIX C

PEER AND SELF EVALUATION RUBRIC FOR ELEMENT BIOGRAPHY SHEET

Exchange your paper with a partner and have them fill out this rubric.

Name of person who is grading this paper: _____

PEER-EVALUATION

	4	3	2	1	What grade would you give your partner? Why?
I can explain the discovery (history) and common uses of my element.		-MOST answers to the “history” questions from the Element Biography Sheet are completed and thorough.			
I can explain how my element is found in water and the significance of my element in water as it relates to human health.		- MOST answers to “Element Sources and Uses” are completed and thorough with detail specifically as it relates to water.			
I can explain the basic organizing principles of the periodic table.		MOST of the “Basic Information” for the element is answered correctly with detail on the Element Biography Sheet.			

Name: _____ Date: _____ Period: _____

SELF-EVALUATION

	4	3	2	1	What grade would you give yourself right now? Why?
I can explain the discovery (history) and common uses of my element.		-MOST answers to the “history” questions from the Element Biography Sheet are completed and thorough.			
I can explain how my element is found in water and the significance of my element in water as it relates to human health.		- MOST answers to “Element Sources and Uses” are completed and thorough with detail specifically as it relates to water.			
I can explain the basic organizing principles of the periodic table.		MOST of the “Basic Information” for the element is answered correctly with detail on the Element Biography Sheet.			

APPENDIX D
INFOGRAPHIC RUBRIC

	4	3	2	1
I can explain the discovery (history) and common uses of my element.	◇ History section of the infographic is presented in a unique way that is easy to understand, concise and informative.	◇ History section of the infographic is presented in a way that is easy to understand, concise and informative.	◇ History section is included on the infographic, but is lacking information.	◇ History section is NOT included on the infographic, or is extremely lacking in information.
I can describe how my element is found in water and the significance of my element in water as it relates to human health.	◇ Infographic includes the MOST important information from “Element Sources and Uses” in a concise way that specifically relates to water. ◇ Connection is made to the element in DC water and explains implications of the results.	◇ Infographic includes the MOST important information from “Element Sources and Uses” in a concise way specifically relates to water. ◇ Connection is made to the element in DC water, but implications of the results are lacking.	◇ Infographic struggles to discuss the MOST important information from “Element Sources and Uses.” ◇ Connection is made to the element in DC water, but implications of the results are not present.	◇ Infographic is lacking a section on water and your element.
I can explain the basic organizing principles of the periodic table.	◇ The MOST important “Basic Information” for the element is included on the Infographic.	◇ The MOST important “Basic Information” for the element is included on the Infographic.	◇ Infographic struggles to highlight the MOST important “Basic Information” for the element.	◇ Basic organizing principles are incorrect or missing.
I can create a visual representation to display content with accuracy and creativity.	◇ Uses creativity to make it unique and interesting. ◇ Neat, easy to read and includes all required information in detail.	◇ Uses some creativity to make it unique. ◇ Neat, easy to read and includes all required information in some detail.	◇ Not unique in any way. ◇ Neat, easy to read and includes most information.	◇ Infographic does not follow the template and/or is difficult to read.
I can create graphs that accurately display data.	◇ Isotope graph is included, is correct and has an appropriate title, x and y axis labels. ◇ Graph is visually appealing.	◇ Isotope graph is included, is correct and has an appropriate title, x and y axis labels. ◇ Graph is somewhat visually appealing.	◇ Isotope graph is included, is correct and has an appropriate title, x and y axis labels. ◇ Graph is not visually appealing.	◇ Graph is incorrect or missing.
I can use appropriate spelling, grammar, mechanics and conventions.	◇ No more than 1 spelling or grammar mistakes. ◇ ALL mechanics and conventions are correct including	◇ No more than 3 spelling or grammar mistakes. ◇ ALL mechanics and conventions are correct	◇ No more than 5 spelling or grammar mistakes. ◇ MOST mechanics and conventions	◇ More than 5 spelling or grammar mistakes. ◇ Several mechanics and conventions are incorrect.

	punctuation and capitalization.	including punctuation and capitalization.	are correct including punctuation and capitalization.	
Habits of Work				
I focus on learning and staying on task.	◇ Always focused during class work time (100%).	◇ Mostly focused during class work time (80%-99%).	◇ Sometimes focused during class work time (50%-99%).	◇ Rarely focused during class work time (less than 50%).
I revise and improve my work.	◇ All drafts are included and were used to improve work.	◇ Most drafts are included and were used to improve work.	◇ Some drafts are included and were used to improve work.	◇ Drafts are not included.
I strive for neatness, accuracy and thoroughness.	◇ Final presentation is a clear representation of best work.	◇ Final presentation is mostly neat, accurate and thorough.	◇ Final presentation is somewhat neat, accurate and thorough.	◇ Final presentation is obviously not best work.
I use time productively.	◇ Class work time is always used productively and efficiently. ◇ Always asks for help when needed.	◇ Class work time is mostly used productively and efficiently. ◇ Sometimes asks for help when needed.	◇ Class work time is sometimes used productively and efficiently. ◇ Struggles to ask for help.	◇ Class work time is rarely used productively and efficiently. ◇ Never asks for help.

APPENDIX E
MISSING WORK REFLECTION

Name _____ Period _____

Missing Work Reflection

You must complete this form if you did not complete the FIRST DRAFT of your Elements in Our Water Biography Sheet.

Title of the Assignment: _____

Date that it was due: _____

Date you will be handing it in: _____

Check all that apply: _____ I was forgetful _____ I was lazy _____ I did not understand the assignment

Other _____

Explain why you checked the box above.

Since you have not turned in your first draft you will need to find someone to peer edit your report. Who will that person be? How will you ensure that you bring your SECOND draft on the required due date?

Who is your advisor? (Your advisor will be contacted if this report may affect your ability to pass chemistry).

Student Signature _____ Date: _____

APPENDIX F
JUDGES RUBRIC

Element Symposium Presentation Rubric

Student Name: _____ Period: _____ Date: _____ Judge Name: _____		Exceeds Expectation	Meets Expectation	Approaching Expectation	Does Not Meet Expectation
		4	3	2	1
Presentation					
	Holds attention of entire audience with the use of direct eye contact, clear voice and correct pronunciation.				
	Uses appropriate pacing and timing throughout presentation and is confident about their knowledge.				
Content					
	Can thoroughly explain the basic information and history of the element.				
	Can explain with detail how the element is found in water including: ◇ How it gets there ◇ Maximum contaminant levels and implications of levels for DC ◇ How it can be tested and removed ◇ How it affects humans				
	Can explain the atomic structure and Lewis dot structure of their element.				
	Demonstrates full knowledge of content by answering all questions with explanations and elaboration.				

Questions to ask presenters:

1. What are the isotopes of your element? *(This should be on their Infographic).*
2. What is an isotope? *(An element with the same number of protons, but different number of neutrons or different mass).*
3. What does the Lewis Dot Structure represent? *(The valence electrons).*
4. If needed you can also ask: what are valence electrons? *(Electrons in the outer energy shell).*

****Students should pretty much be an expert on anything/everything on their Infographic, so ask any questions you think would be helpful.****

APPENDIX G
ELEMENT PROJECT REFLECTION

NAME: _____ PERIOD: _____ DATE: _____

ELEMENTS IN OUR WATER PROJECT REFLECTION

1. What steps were required in order to complete this project/presentation?

--

2. What was challenging about making the Infographic?

--

3. What was challenging about your presentation during the Elements in our Water Poster Symposium?

--

4. Did you enjoy completing the Elements in our Water Infographic? Why or why not?

--

5. Are you proud of the work you did on this project? Why or why not?

--

6. What did you do well on this project/presentation?

7. How could your work on this project have been improved?

8. Do you think we should continue the Elements in our Water Poster Symposium next year? Why or why not?

9. What do you think we could improve on if we continue the Element Poster Symposium next year? Give at least one suggestion.

10. Do you think the Elements in our Water project helped you learn the topics of atomic structure, isotopes, Lewis structures and graphing? Explain why or why not.

APPENDIX H
CHEMISTRY SURVEY QUESTIONS

Chemistry Survey Questions (in Google Forms)

1. How interested are you in the chemistry topics we are discussing right now on a scale of 1-5 (1 being not at all interested and 5 being very interested)?	2. Why did you answer the way you did to the above question?	3. What is your favorite thing that we have done in chemistry so far? Why?	4. What is your least favorite thing that we have done in chemistry so far? Why?	5. Do you think you were more interested in chemistry when we were doing one of your favorite things? Explain.	6. What would help increase your interest and motivation in chemistry? Be specific.
--	--	--	--	--	---

APPENDIX I
OBSERVATION FORM

Chemistry Observation

Class Period: _____

Time of Observed Lesson: _____

Date of observation: _____

Part I: Ratings of Key Indicators

	Not at all					To a great extent					Don't Know	N/A
1. The science content was significant and worthwhile.	1	2	3	4	5	6	7					
2. The science content was appropriate for the developmental levels of the students in this class.	1	2	3	4	5	6	7					
3. Students were intellectually engaged with important ideas relevant to the focus of the lesson.	1	2	3	4	5	6	7					
4. The teacher displayed interest and enthusiasm about the science concepts (e.g., in his/her dialogue with students).	1	2	3	4	5	6	7					
5. Science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification.	1	2	3	4	5	6	7					
6. Appropriate connections were made to other areas of science, to other disciplines, and/or to real-world contexts.	1	2	3	4	5	6	7					

Part II: For the following statements rate the teacher's impact as negative, mixed/neutral or positive.

7. Students' understanding of science as a dynamic body of knowledge generated and enriched by investigation.

Negative effect		Mixed or Neutral Effect		Positive Effect
1	2	3	4	5

Comments:

8. Students' ability to apply or generalize skills and concepts to other areas of science, other disciplines, and/or real-life situations.

Negative effect		Mixed or Neutral Effect		Positive Effect
1	2	3	4	5

Comments:

9. Students' active engagement in doing science.

Negative effect		Mixed or Neutral Effect		Positive Effect
1	2	3	4	5

Comments/Evidence:

10. Students' perceived interest in and/or appreciation for the discipline.

Negative effect
1

Mixed or Neutral Effect
2 3

4 Positive Effect
5

Comments/Evidence:

--

Part III: Short answer responses

11. Describe the teacher's overall motivation level and evidence to support your response.

--

12. Describe the students' overall motivation level and evidence to support your response (i.e. their willingness to complete the assigned tasks, their interest level, etc.).

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APPENDIX J
PRE AND RETENTION TEST

Name: _____ Period: _____ Date: _____

ATOMS AND ELEMENTS PRE-QUIZ

LT 1: I can describe the number and arrangement of subatomic particles within an atom or ion. _____/6 = _____

Part I: Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question. *2 points each.*

- _____ 1. A subatomic particle that has about the same mass as a proton, but with no electrical charge, is called a(n)
 a. nuclide. c. Electron.
 b. neutron. d. isotope.
- _____ 2. All isotopes of hydrogen contain
 a. one neutron. c. one proton.
 b. two electrons. d. two nuclei.
- _____ 3. The mass of an atom is mostly contained in the:
 a. protons and neutrons c. electrons and neutrons
 b. protons and electrons d. protons only
- _____ 4. The subatomic particle that is involved in bonding is called a (n):
 a. electron c. neutrons
 b. protons d. nucleus

Choose true or false for each question.

4. T F The Atomic Mass reported on the periodic table is a weighted average of all isotopes of that element. _____
5. T F Isotopes are two atoms of the same element with different numbers of protons. _____

LT 2: I can calculate the average atomic mass using the relative abundance of an element. _____/2 = _____

6. The average atomic mass is based on the:
- relative abundance of each isotope
 - the average of all elements on the periodic table
 - the average of all the elements in a group
 - none of the above

Using the isotopic data below, calculate the average atomic masses of the following elements. Choose the correct answer

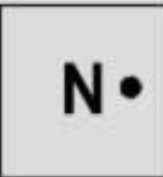
7. Calculate the average atomic mass of Bromine.

Isotope	Mass	Abundance
Br-79	78.92	50.7%
Br-81	80.92	49.30%

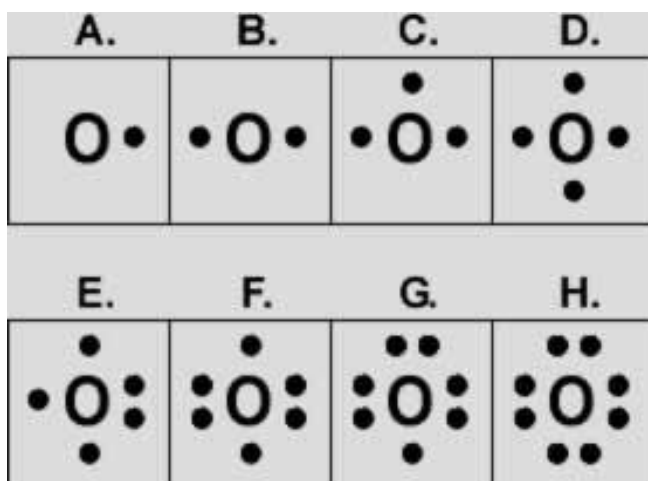
- 40.0
- 79.9
- 159.84
- 80.0

LT 3: I can create the Lewis structure of an element. _____/3 = _____

8. Which is the correct Lewis structure for nitrogen?

A.	B.	C.	D.
			
E.	F.	G.	H.
			

9. What is the correct Lewis structure for oxygen?



10. The purpose of a Lewis diagram is to show:

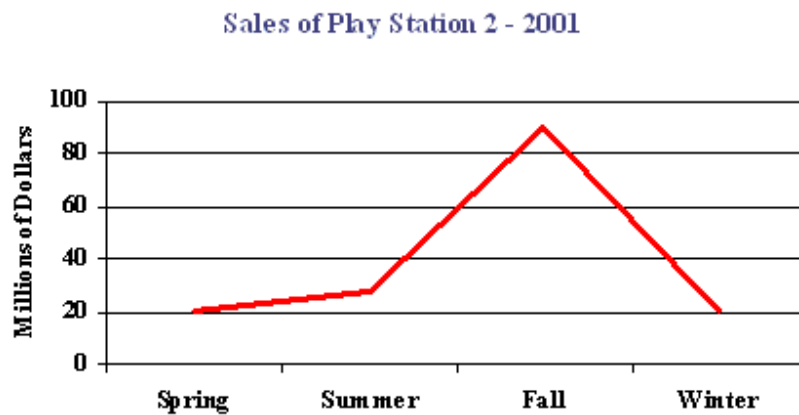
- the number of protons
- the number of electrons
- the number of valence electrons
- the number of neutrons

LT 4: I can create graphs that accurately display data. _____/5 = _____

11. The x-axis should contain which variable?

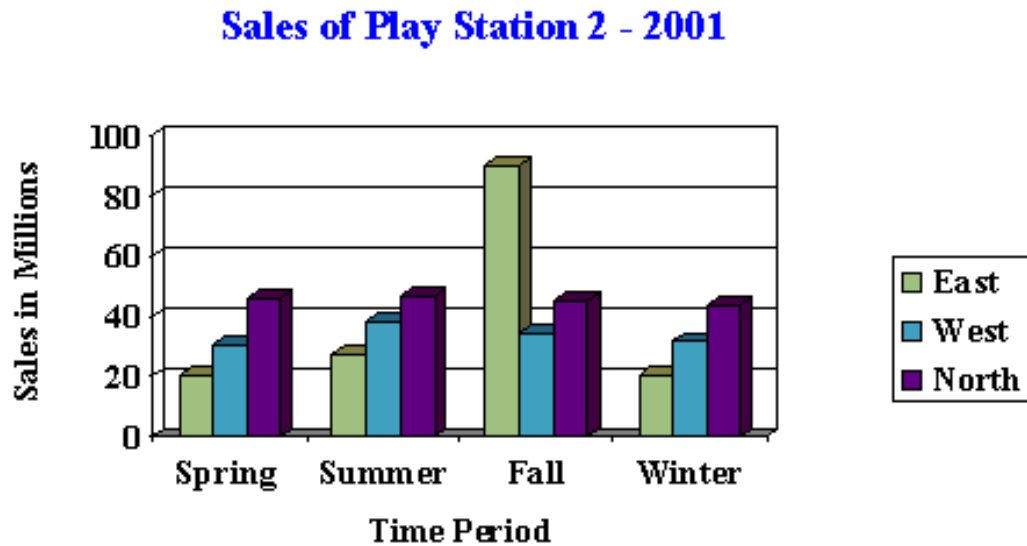
- the dependent variable
- the independent variable
- the controlled variable
- all of the above

Use the graph below to answer number 12.



12. What is the purpose of this graph?
- a. To show change over time
 - b. To compare amounts
 - c. To find differences in height
 - d. None of these
13. What is the purpose of the title?
- a. To show sales; that sales are in millions
 - b. To show the seasons of the year
 - c. To describe the graph
 - d. None of the above

Use the graph below to answer the following questions:



14. What were the sales of Play Station 2 in the East during the Spring?

- a. About 20 million dollars
- b. About 30 million dollars
- c. About 80 million dollars
- d. About 90 million dollars

15. What is the purpose of this graph?

- a. To show change over time
- b. To compare amounts
- c. To find differences in height
- d. None of these

APPENDIX K

POST-TEST

Unit 2 Test

LT: I can construct a diagram and describe the number and arrangement of subatomic particles within an atom or ion. _____/5 =

1. What is an isotope?

2. What is the difference between Carbon-12 and Carbon – 14?

3. Fill in the chart below:

Element Name	Neutrons	Protons	Electrons	Mass Number	Atomic Number
		12		25	
Chlorine –	18				
Strontium -				88	

Relative Abundance

1. Naturally occurring europium (Eu) consists of two isotopes was a mass of 151 and 153. Europium-151 has an abundance of 48.03% and Europium-153 has an abundance of 51.97%. What is the atomic mass of europium?

SHOW ALL WORK

Isotopes	Percentage of Isotope
Eu- 151	48.03%
Eu - 153	51.97%

1. Strontium consists of four isotopes with masses of 84 (abundance 0.50%), 86 (abundance of 9.9%), 87 (abundance of 7.0%), and 88 (abundance of 82.6%). Calculate the atomic mass of strontium.

Isotopes	Percentage of Isotope
Sr-84	0.50%
Sr-86	9.9%
Sr-87	7.0%
Sr-88	82.6%

Bohr Models

Draw the Bohr model for the following elements:

Boron

of P:

of N:

of E:

Fluorine

of P:

of N:

of E:

Nitrogen

of P:

of N:

of E:

Oxygen

of P:

of N:

of E:

Periodic Groups:

LT: I can explain the basic organizing principles of the periodic table. ____/9 =

4. What is the group name of the following elements?

a. Sulfur _____

b. Calcium _____

c. Iodine _____

d. Iron _____

Using the periodic table below:

5. Color the alkali metals yellow.

6. Color the noble gases green.

7. Color the transition metals blue.

The Periodic Table of the Elements																		1 H Hydrogen 1.01		2 He Helium 4.00																									
3 Li Lithium 6.94		4 Be Beryllium 9.01																5 B Boron 10.81		6 C Carbon 12.01		7 N Nitrogen 14.01		8 O Oxygen 16.00		9 F Fluorine 19.00		10 Ne Neon 20.18																	
11 Na Sodium 22.99		12 Mg Magnesium 24.31																13 Al Aluminum 26.98		14 Si Silicon 28.09		15 P Phosphorus 30.97		16 S Sulfur 32.07		17 Cl Chlorine 35.45		18 Ar Argon 39.95																	
19 K Potassium 39.10		20 Ca Calcium 40.08		21 Sc Scandium 44.96		22 Ti Titanium 47.87		23 V Vanadium 50.94		24 Cr Chromium 52.00		25 Mn Manganese 54.94		26 Fe Iron 55.85		27 Co Cobalt 58.93		28 Ni Nickel 58.69		29 Cu Copper 63.55		30 Zn Zinc 65.39		31 Ga Gallium 69.72		32 Ge Germanium 72.61		33 As Arsenic 74.92		34 Se Selenium 78.96		35 Br Bromine 79.90		36 Kr Krypton 83.80											
37 Rb Rubidium 85.47		38 Sr Strontium 87.62		39 Y Yttrium 88.91		40 Zr Zirconium 91.22		41 Nb Niobium 92.91		42 Mo Molybdenum 95.94		43 Tc Technetium (98)		44 Ru Ruthenium 101.07		45 Rh Rhodium 102.91		46 Pd Palladium 106.42		47 Ag Silver 107.87		48 Cd Cadmium 112.41		49 In Indium 114.82		50 Sn Tin 118.71		51 Sb Antimony 121.76		52 Te Tellurium 127.60		53 I Iodine 126.90		54 Xe Xenon 131.29											
55 Cs Cesium 132.91		56 Ba Barium 137.33		57 La Lanthanum 138.91		72 Hf Hafnium 178.49		73 Ta Tantalum 180.95		74 W Tungsten 183.84		75 Re Rhenium 186.21		76 Os Osmium 190.23		77 Ir Iridium 192.22		78 Pt Platinum 195.08		79 Au Gold 196.97		80 Hg Mercury 200.59		81 Tl Thallium 204.38		82 Pb Lead 207.2		83 Bi Bismuth 208.98		84 Po Polonium (209)		85 At Astatine (210)		86 Rn Radon (222)											
87 Fr Francium (223)		88 Ra Radium (226)		89 Ac Actinium (227)		104 Rf Rutherfordium 178.49		105 Db Dubnium (262)		106 Sg Seaborgium (266)		107 Bh Bohrium (264)		108 Hs Hassium (269)		109 Mt Mitnerium (268)		110 Ds Darmstadtium (281)		111 Rg Roentgenium (272)		112 Cn Copernicium (285)																							
																		58 Ce Cerium 140.12		59 Pr Praseodymium 140.91		60 Nd Neodymium 144.24		61 Pm Promethium (145)		62 Sm Samarium 150.36		63 Eu Europium 151.96		64 Gd Gadolinium 157.25		65 Tb Terbium 158.93		66 Dy Dysprosium 162.50		67 Ho Holmium 164.93		68 Er Erbium 167.26		69 Tm Thulium 168.93		70 Yb Ytterbium 173.04		71 Lu Lutetium 174.97	
																		90 Th Thorium 232.04		91 Pa Protactinium 231.04		92 U Uranium 238.03		93 Np Neptunium (237)		94 Pu Plutonium (244)		95 Am Americium (243)		96 Cm Curium (247)		97 Bk Berkelium (247)		98 Cf Californium (251)		99 Es Einsteinium (252)		100 Fm Fermium (257)		101 Md Mendelevium 268.10		102 No Nobelium (259)		103 Lr Lawrencium (262)	

8. Choose **TWO** groups below and write **ONE** characteristic of each.

Halogens -

Noble Gases -

Alkali Metals -

Alkaline Earth Metals -

Transition Metals -

LT: I can draw the Lewis dot structure of an element. _____/4 =

14. Draw the Lewis dot structure for the following elements:

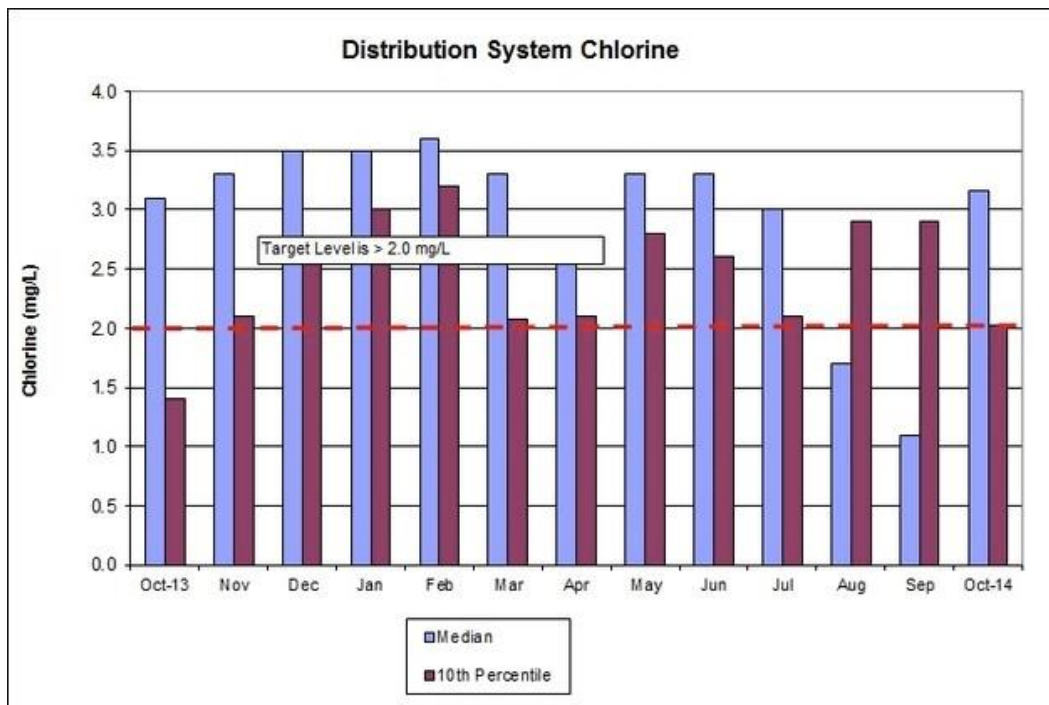
A. Li

B. Ca

C. Sb

D. Rn

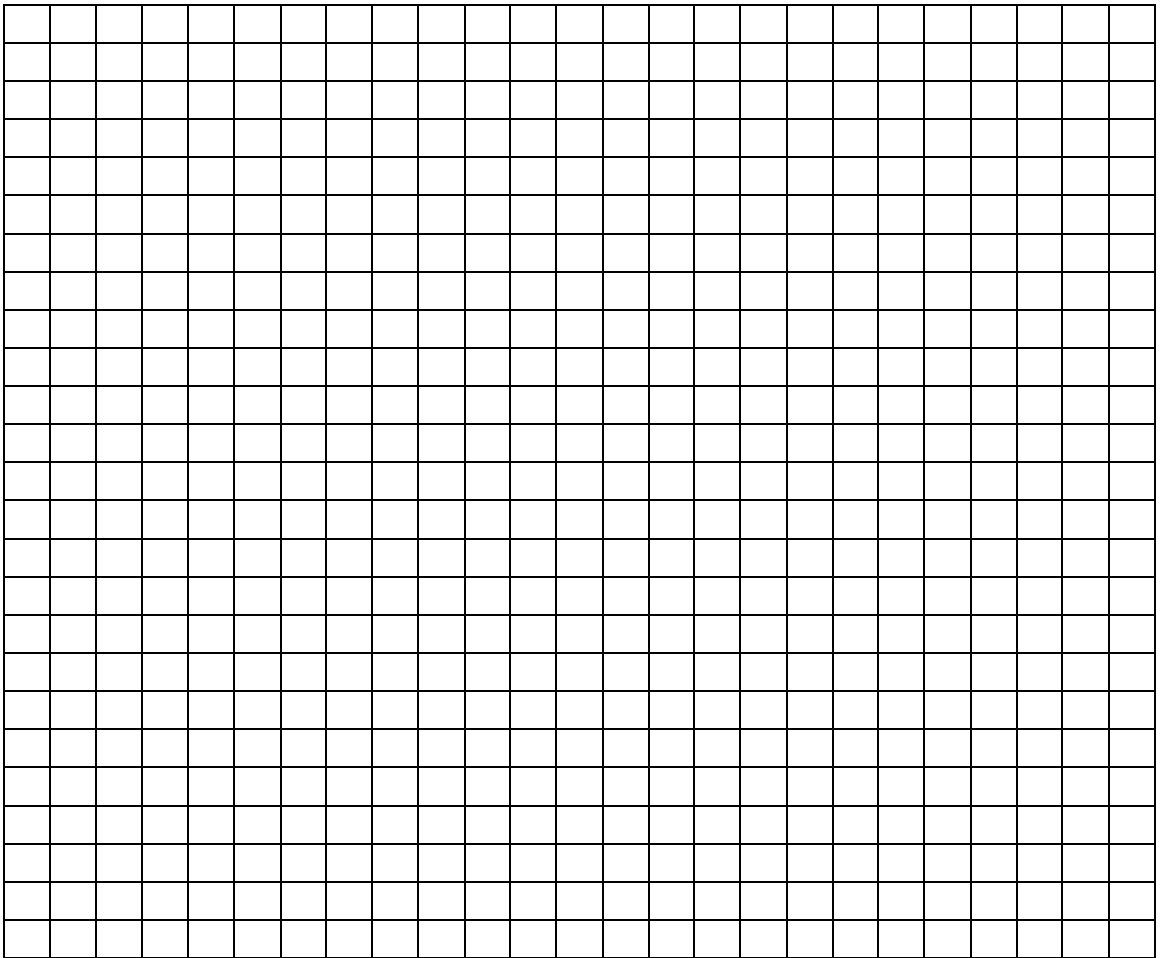
LT: I can create graphs that accurately display data.



15. What does the graph above show? (Hint: this was taken from the DC water website).

16. Graph the following data, which shows the average grade in each chemistry class:

Class period	Average Grade
Period B	3.5
Period D	2.0
Period E	2.5
Period F	2.7
Period G	2.5



APPENDIX L

ANOVA DATA FOR PRE AND RETENTION TEST

Table 2
ANOVA data for pre, post and retention test

	Pre and post	Pre and Retention	Post and retention	Mean Pre-test	SD Pre-test	Mean Post-test	Standard Deviation post-test	Mean retention test	SD retention test
Overall Average	P<.01	P<.05	NS	43.3594	14.0148	64.3552	23.7223	58.3228	23.6821
B period Average	P<.05	NS	NS	50.4464	13.079	71.4706	23.1651	67.5	21.5473
F period Average	P<.05	NS	NS	37.8472	12.4026	57.9887	22.9485	52.2059	23.5871
Males	NS	P<.05	NS	38.0682	10.6267	55.1517	201.1642	57.6923	20.9093
Females	P<.05	NS	NS	47.3684	13.3911	68.4246	25.0208	60.2941	26.9676
Honors	P<.05	NS	NS	51.7857	12.3503	82.7375	20.5391	75	26.5165
SPED	NS	NS	NS	46.875	14.878	58.9627	18.797	47.5	12.8695

APPENDIX M

ELEMENT PROJECT REFLECTION DATA

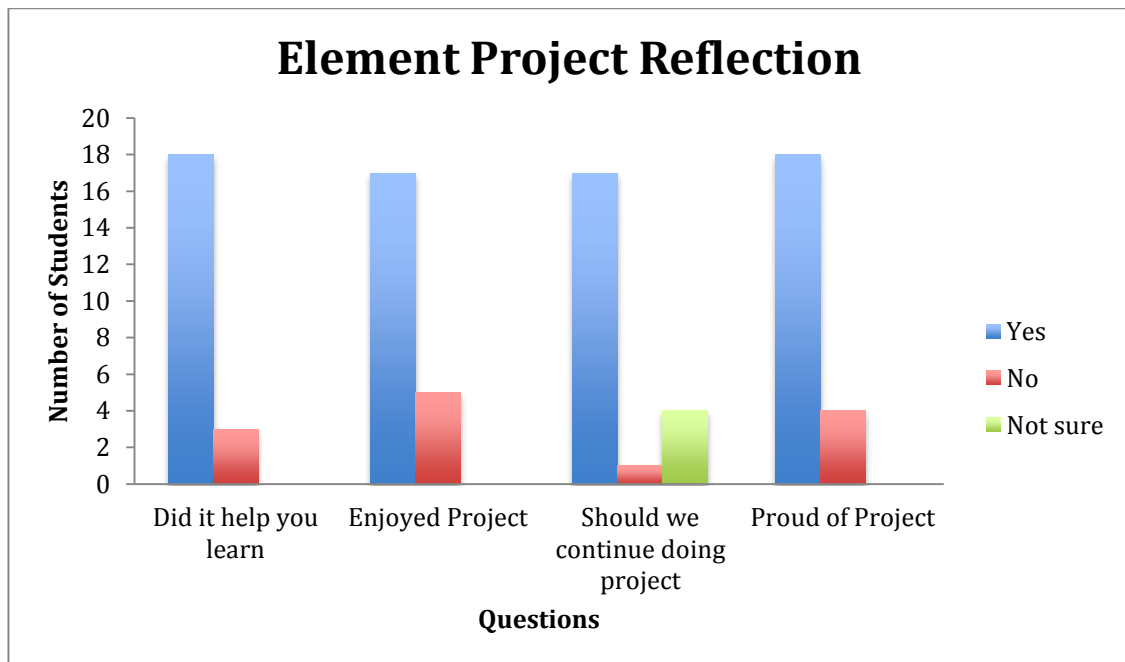


Figure 6: Overall responses to Elements in our Water Project reflection.

APPENDIX N
IRB EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

966 Technology East Room 127
 c/o Technology & Infectious Diseases
 Montana State University
 Bozeman, MT 59717
 Telephone: 406-994-6783
 FAX: 406-994-4303
 Email: Cheryl@montana.edu

Chair: Mark Quinn
 406-994-5721
 mquinn@montana.edu
 Administrator:
 Cheryl Johnson
 406-994-6783
 cheryl@montana.edu

MEMORANDUM

TO: Liane McGillen and Walt Woolbaugh
FROM: Mark Quinn, Chair *Quinn*
DATE: October 15, 2014
RE: *"How Does the Use of Practical Applications Taught across Several Topics Impact Students' Mastery of Chemistry Content?"* [LM-C101514-EX]

The above research, described in your submission of October 15, 2014, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- ☒ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- ☒ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- ☐ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- ☐ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- ☐ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- ☐ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.