

PROJECT-BASED LEARNING
IN THE SECONDARY CHEMISTRY CLASSROOM

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Physical Science- Interdepartmental- Master of Science

2015

ABSTRACT

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This study investigated the use of project-based learning (PBL) in a high school chemistry classroom. PBL encourages the use of projects, which promote continual learning, rather than a summative project at the end of a unit after the learning has already been done. Along with implementing PBL, the study also incorporated many of the strategies included in the broader strategy known as Assessment *for* Learning (AfL), which stresses developing assessments that are part of the learning process rather than simply a measurement of the amount of learning that has occurred upon completion of a unit.

The hypothesis of this research was that PBL would increase student comprehension and motivation as measured through pre and post-test data and a student survey. The new project-based unit required students to research and present the properties and structures of elements and how we use them. The expectation was that this approach would engage students with the material, the computer modeling would allow for more concrete visualization of structures and the project-based format would allow students to become more invested in their own learning.

This study provided evidence to support the hypothesis that the implementation of project-based learning, supported by formative assessment and other assessment *for* learning strategies, will improve student comprehension and motivation in the secondary chemistry classroom.

ACKNOWLEDGEMENTS

There are a number of people who provided assistance and support during the completion of this thesis. My advisor, Dr. Merle Heidemann, was instrumental in teaching me the scientific and research skills necessary for the work of writing a thesis. She also guided me through the development of the classroom unit and editing of this thesis with unwavering honesty and pragmatism. I greatly appreciate her help and feel that it made an otherwise daunting task seem manageable and even enjoyable.

I also appreciate the support of the other members of my cohort: Bryan Taisor, Dan Schuchardt, Dusti Vincent, Courtney Lutz and Michelle Hamilton. We spent long hours together working on our projects and I benefited from their willingness to share ideas and help me problem solve challenges as they arose.

My family has provided both emotional and financial support without me ever having to ask for either. Thank you to my parents for always encouraging me to pursue my passions, in this endeavor and in many others. Thank you to my Uncle Dave and Aunt Laurie for taking an interest in my academic pursuits and providing guidance based on their own experiences as academics. Last, but not least, thank you to my husband Jared who understands my need to continue taking on new challenges and supports me even when it means sacrificing time together or money in our wallets.

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INTRODUCTION

Rationale and Statement of the Problem

This study investigated methods for teaching the organization of the periodic table and structure of the atom in a high school chemistry classroom. These topics were selected because they generally occur at the beginning of the first trimester chemistry course. In the past, the study of the periodic table required a large amount of memorization of vocabulary, which made it boring for many students, while the section on atomic structure was challenging due to the abstract nature of models such as electron configurations and Lewis dot diagrams.

The hypothesis of this action-research was that project-based learning would improve student comprehension and motivation as measured through pre and post-test data and a student survey. This project-based unit required students to research and present the properties and structures of elements and how we use them. The expectation was that this more personal approach would engage students with the material, the computer modeling would allow for more concrete visualization of structures and the project based format would allow students to become more invested in their own learning.

This project occurred at the beginning of the first trimester of chemistry, so students did not have any background knowledge, except for what they may have retained from middle school science classes. Following this unit, students studied chemical nomenclature and bonding of binary ionic and covalent compounds along with nomenclature of acids. During the second trimester of chemistry, students studied states of matter, gas laws and stoichiometry.

The theoretical framework of this study included not only project based learning, but also formative assessment and other strategies known collectively as assessment *for* learning.

Project Based Learning

Project-based learning (PBL) is a strategy that encourages projects, which promote continual learning, rather than “busy work” or a summative project at the end of a unit after the learning has already been done. These projects center on driving questions that promote meaningful inquiry and fulfill specific educational purposes (Larmer and Mergendoller, 2010). A review of the literature found that many educators are implementing this strategy in their classrooms in order to increase both student learning and student motivation.

Lam et al. (2009) reconfirmed the findings of previous studies that students were more intrinsically motivated to produce high quality work when they were given choices. This study focused on 126 Hong Kong secondary teachers and their 631 students during a semester long project based learning program. The researchers found that teacher motivation to implement PBL was directly related to student motivation during the project. In Hong Kong, many teachers were required to implement PBL and those who were doing so against their will often provided less instructional support during the project, which in turn decreased student motivation. This study served as an important reminder that although the PBL was student centered, the teacher still needed to play an active role in engaging and guiding student learning.

PBL was also promoted in Taiwan and a study by ChanLin (2008) followed a 5th grade classroom (ages 10-11) through the implementation of a technology supported science project. In this project, students were grouped in 4-5 person teams to develop research questions related to geographical, ecological and historical exploration about the places where they lived. Students incorporated technology such as digital cameras and websites to present their findings. The project design also emphasized clear goals, multiple opportunities for formative assessment and

revision. Science teachers emphasized the use of students' own interpretation of knowledge, which required careful reading of information to avoid misinterpretation and synthesizing information from multiple sources.

Generally, the students involved in this study reported a positive experience. Students showed a gradual increase in skills for handling simple and complex tasks. Researchers observed student achievement of learning goals in synthesis and elaboration of knowledge, action in engagement of scientific exploratory tasks and use of technology for supporting and reporting their research. Students also developed basic computer skills and conceptual understanding of scientific observation and ways of conducting research. Finally, students experienced learning by doing and were coached by their science teacher. They also learned various basic skills from peer to peer teaching. Students generally enjoyed the experience using the web page editor to present the project and reported feelings of engagement, concentration, confidence and success. However, some students experienced feelings of frustration and failure, especially when they encountered obstacles in using the technology. One teacher noted that ““Kids were helping each other when they encountered obstacles. For them this is also a way of learning””. Teachers also reported that the website design tool helped engage students in organizing their knowledge.

This study provided strong support for the implementation of technology supported PBL in the classroom. It also cited two previous studies that supported their hypothesis that technology instruction was more effective when integrated with other learning strategies in order to provide a meaningful context and promote student motivation. Chen and McGrath (2003) suggested that the use of hypermedia tools could sustain students' motivation and cognitive engagement. The use of the Internet for research or developing a web site to publish their project

results could enhance students' organizational skills, connect them with a real audience and foster a better understanding of the World Wide Web (Trauth-Nare and Buck 2011).

It was interesting to compare the ChanLin (2008) study of 5th grade students in Taiwan with the Zhenyu (2012) study of 22 teachers of six and seventh graders from Shanghai, China. The teachers in this study emphasized many challenges that they experienced during their study. For example, the students had limited access to computers and therefore had to share computers with other groups. The researchers noted that during research time the students relied heavily on Internet research. Their Internet searches often resulted in sources that were not credible or at a reading level that was too advanced and incorporated vocabulary they did not understand. The researchers felt students were not discerning and "blindly believed their results to be absolute truths and without any need for further reflection". Additionally, some students were identified playing computer games and engaging in other off task behavior. As a result of all these problems the process of data collection was much more time consuming than originally planned.

Rubrics were one way to reduce off task behavior by communicating structured expectations to students. Martinez and de Pablo (2011) argued for the benefit of rubrics in providing formative assessment opportunities for the student and teacher. They explained that rubrics were an excellent way to establish communication between the student and the teacher about criteria and quality demanded by the teacher. They allowed the student to know, right from the start, how to do their work and ensured a fair assessment of each student's work.

Along with allowing for peer and teacher feedback, rubrics were one aspect of PBL that allowed for student self-regulation, because students could self-assess their own work and also respond to peer and teacher feedback before final submission of the project. Stefanou et al. (2013) suggested that self-regulation was the key to what made project based learning successful.

They referenced previous research, which compared high school biology students receiving lecture-based instruction to those receiving a PBL approach. The students in the PBL classroom reported being more intrinsically motivated at the end of the 6-week experiment than students in the traditional classroom. The students using the PBL approach also ranked the importance of the task higher than those in the traditional classroom.

Barak and Dori (2005) observed the integration of Internet based computer molecular models into project-based learning. This study was conducted at the Technion Israel Institute of Technology and investigated 215 students who participated in three general chemistry courses taught by the same instructor and several teaching assistants. One of the courses employed project-based learning, while the other did not. Academic ability and motivational levels between the control and experimental groups were not found to be statistically significant.

As part of the PBL approach, each assignment required the students to investigate a specific concept and produce computerized models as the end products of the learning activity. The analysis of the post-test and the final examination showed that the experimental group scored significantly higher in both the post-test and the final examination. The students who participated in the PBL gained better chemistry understanding compared to their control group peers. The data also showed that the experimental group students earned significantly higher scores than their control group classmates in the higher-level synthesis questions. Barak and Dori (ibid) concluded:

“Incorporating chemistry PBL into higher education enhanced students’ understanding of chemical concepts, theories, and molecular representations. The construction of computerized models and Web-based inquiry activities promoted

students' ability of mentally traversing the four levels of chemistry understanding: symbolic, macroscopic, microscopic, and process".

They also noted that their findings strengthen the claim of previous studies, which found that computerized models could assist students in generating mental images of abstract ideas.

Kunberger (2013) addressed practical time constraints in a project-based classroom in a paper that described the revision of an upper level geotechnical engineering design course to include PBL. His results indicated that students enjoyed the project-based nature of the course and did not feel there were any major negative affects from reducing the structured lecture time of the class. He concluded that the students recognized the benefits of an independent, student-led approach to learning. The instructor of this course found that primary topics could still be covered and what was sacrificed in breadth was compensated for in depth. The instructor reported that the redesigned course provided a more meaningful experience for students.

One of the most helpful articles in terms of practical advice for developing appropriate PBL units was written by Lattimer and Riordan (2011) and reported research results from students and teachers at a high tech middle school in San Diego. The researchers warned against designs that focused too much on the "project" and not enough on the learning. In order to address this potential problem, teachers at High Tech High (HTH) charter school relied on Adria Steinberg's six "A's" of design: academic rigor, authenticity, applied learning, active exploration, adult connections, and assessment practices. *Academic rigor* addressed key learning concepts or standards. *Authenticity* used a real-world context and addressed issues that mattered to the students. *Applied learning* engaged students in solving problems that required skills expected in high-performance work organizations such as teamwork, problem-solving, communication. *Active exploration* extended the projects beyond the classroom. *Adult connections* connected

students with adult mentors and coaches from the wider community. *Assessment practices* involved students in regular exhibitions and assessments of their work. Lattimer and Roirdan (2011) reported that “consistent use of PBL grounded in the six A’s of project design has resulted in high levels of student engagement, innovative and responsive teaching practices, and a school community that is dedicated to learning”.

One of the most convincing arguments in favor of PBL was the research of Wurdinger et al. (2007). The principal of Dakota Meadows Middle School (DMMS) in Mankato, Minnesota asked the authors of this article to help the school integrate PBL into the curriculum. The authors reviewed previous research on PBL and identified numerous benefits of PBL: it is active, not passive; it is interesting and relevant to the student; it allows for autonomy and self-directed learning; it increases communication skills; and it enhances motivation to learn.

The authors defined PBL as “a teaching method where teachers guide students through a problem-solving process which includes identifying a problem, developing a plan, testing the plan against reality, and reflecting on the plan while in the process of designing and completing a project”. Wurdinger et al. (ibid) determined that the effectiveness of PBL would be measured by two related elements: teacher acceptance and student engagement.

The results of end of the year teacher interviews showed high levels of teacher acceptance through the use of words like *excitement, challenging, holistic, higher level thinking, ownership, comprehension, and retention* when describing project-based learning in their classrooms. The teachers seemed to realize that students were engaged and enjoying the process, which is why they continued using PBL in their classrooms. The authors observed a strong commitment to the process because most teachers were excited to ask questions about the process and discuss possible solutions to those questions.

Teacher interviews also provided evidence of student engagement. For example, teachers mentioned that students were focused and excited about doing their projects and that they could observe the level of engagement by watching students in class. The researchers also concluded that lecturing created a situation where students felt they needed to memorize the information for a test, whereas the PBL created a situation where students were solving problems and thinking their way through the steps of the inquiry process.

Chun-Ming et al. (2012) assigned 117 Taiwanese fifth grade students to experimental and control groups. Students in the experimental group used a web-based information-searching system to collect data on the Internet and Microsoft's Photo Story was used to help the experimental group develop movies for storytelling based on the collected data. Students in the control group collected data on the Internet, but without the web-based information system and created PowerPoint presentations rather than video. The researchers administered self-designed assessments including a science learning motivation scale, problem-solving competence scale and science achievement test to evaluate the learning performance of the students in both groups.

The score of the experimental group was significantly higher on the evaluations of science learning motivation, problem-solving competence and science learning achievement of the students. Researchers also noted that the variance resulting from gender was not significant. The project-based learning with digital storytelling could therefore effectively promote the science learning motivation, the problem-solving competence, and the science learning achievement of both genders. The analysis of these results included a reference to a previous study which suggested that a technology-integrated PBL environment provides a real-world, constructivist, cooperative learning environment that has many advantages over the traditional PBL environment. The researchers also suggested that the use of a web-based informational

system allowed students to better organize their research, which increased their ability to answer higher-level questions.

Guthrie (2010) also explored the potential benefits of technology supported PBL, this time specifically for students with a variety of learning styles. In this experiment, PBL was implemented in a post-secondary French business school course of 382 students. In this project, students were required to complete online courses along with engaging in group work and classes with direct instruction. A series of online classes were made available to provide students with reference materials to complete specific parts of the project. The researchers hypothesized that the heavy reliance on technology in the project would only be beneficial for students with abstract learning styles, but found that hypothesis was not supported. The researchers concluded, “Students with a preference for abstract conceptualization to concrete experience do not perceive online resources as more useful than other students”.

In summary, this review of the research showed strong support for the use of project based learning to improve student motivation and understanding.

Assessment for Learning

Along with implementing PBL, the study reported here also incorporated many of the strategies included in the broader strategy known as *Assessment for Learning* (AfL), which stresses developing formative assessments that are part of the learning process rather than simply a measurement or judgment of the amount of learning that has occurred upon completion of a unit of study.

Mehmood et al. (2012) define formative assessment as:

“The diagnostic use of assessment to provide feedback to teachers and students over the course of instruction...It stands in contrast to summative assessment, which generally takes place after a period of instruction and requires making a judgment about the learning that has occurred e.g., by grading or scoring a test or paper”.

Generally, formative assessment allowed the teacher to determine the students' levels of understanding and make necessary instructional adjustments. It also empowered learners to identify any gaps in their own knowledge and provided feedback on how to make adjustments in order to achieve their own learning goals. Mehmood et al. (ibid) emphasized that although the teacher often generated formative assessment, students could also take a more active role when engaged in self or peer assessment. They discussed two studies that showed students who understood the learning objectives and assessment criteria and had opportunities to reflect on their work showed greater improvement in content knowledge than those who do not. These studies showed that effective feedback included specific comments about errors and suggestions for improvement and encouraged students to focus their attention on the task rather than on simply getting the right answer.

Mehmood et al. (ibid) studied sixty 10th grade students who were divided into two groups. The control group received traditional instruction, while the experimental group received formative assessment during instruction. Pre and post-tests were administered to both groups; the experimental group showed a statistically significant increase in post-test score as compared to the control group. This would suggest that formative assessment was effective in improving student learning outcomes.

Another study of a school in Scotland making a transition to Assessment *for* Learning style formative assessment showed less clear results. Smith and Gorard (2005) placed students ages 14-15 in one of four groups. Three groups continued with the previous school policy of receiving marks and grades on their work, while the treatment group did not receive marks or grades, but instead had more careful, individual formative feedback from their teachers. Throughout the semester, tests were administered to both control and treatment groups, but only the control groups were given access to their grades. The researchers compared summative grades between the control and treatment groups. The results showed that the control group earned higher marks than the experimental group. The student interviews revealed that many of the teachers in the treatment group did not provide specific feedback with instructions on how to improve, but rather made comments such as “very good” or “try harder next time”. Finally, the researchers also suggested that the lower performance in the treatment group may have been, in part, due to the fact that only one of the four aspects of AfL strategies was implemented. There was no evidence that teachers employed other methods of formative assessment such as peer or self-assessment.

The findings of both Smith and Gorard (ibid) and Hargreaves (2005) concluded that a paradigm shift in teachers’ thinking was necessary for successful implementation of AfL. Hargreaves drew on a survey of 83 teachers in order to explore their conceptions of ‘assessment for learning’, ‘assessment’ and ‘learning’. Hargreaves found that for many teachers, assessment was equated with measurement or determining the amount of a student’s learning, often through testing. For other teachers, assessment was equated with inquiry. From this perspective, the purpose of assessment was a deeper understanding of individuals as learners, so assessment was viewed as part of the learning process rather than separate from it.

Similarly, Hargreaves interpreted two conceptions of learning: learning as attaining objectives; and learning as constructing knowledge. Metaphors such as “next steps” and “move forward” suggested learning occurs in predictable and measureable steps. On the other hand, learning as knowledge construction suggested that students were actively involved in making sense of the world around them by making connections between previous knowledge and new experiences.

Hargreaves proposed that if assessment was viewed as part of the learning process then assessment *for* learning might look more like inquiry or investigation than a test. In addition, both teachers and students should emphasize the learning processes rather than performances, since learning should occur without needing the teacher to observe proof. This understanding of AfL fits very easily into PBL where the student has more ownership and responsibility for learning.

Newby and Winterbottom (2011) cited previous research suggesting that self- and peer-assessment strategies allowed students to review their own and others’ work, before revising their own work. This was likely to improve the quality of the final submitted work. This research suggested that since the self and peer assessment strategies took extra time, they were best applied to long-term assignments that gave students a few weeks to practice the technique, receive feedback and make revisions.

Self-assessment activities were generally divided into two categories: criteria and reflection oriented. Bruce (2001) collected data on five high school teachers and their students in order to determine the effect of self-assessment strategies on student engagement and describe challenges faced by teacher in the implementation of these strategies. Criteria-oriented self-assessment involved assessment based on standards. This focused attention on the quality of

student work and coaching students to become able judges of their own work. Reflection oriented activities, on the other hand, had a more inward and subjective focus. They allowed learners to integrate their learning, to consider how to regulate or adjust their learning processes based on criteria, and to attempt to understand their own viewpoints.

Bruce (ibid) presented four recommendations for successful implementation of criteria oriented self assessment: clarity of goals, student involvement in the assessment design, the availability of feedback, and the opportunity to correct one's work in response to the feedback. She cited a number of studies that suggested students needed explicit instruction on self-assessment, because most students found self-evaluation an "unfamiliar and daunting experience". Bruce emphasized that learning to use feedback to improve one's work requires coaching and practice and recommended the use of exemplars for students to practice providing evaluation.

Bruce found that teachers were very positive regarding both types of self-assessment. They felt it improved student "buy-in" and they planned to continue implementation of these activities in the future. The only major hurdles that teachers reported in using this strategy were initial student resistance and time pressure with their curriculum. The data from this study supported the hypothesis that self-assessment increased student engagement in and responsibility for their learning. However, the results did not support students having a more genuine interest in their learning.

Vickerman (2009) studied 90 undergraduate students as they were introduced to peer assessment for the first time. The purpose of this study was to determine the impact of peer assessment on student learning. She described potential advantages of peer assessment for students as increasing: ownership of the assessment, motivation, responsibility for learning, life-

long learning skills, meta-cognition and deep (rather than surface) learning. She also cited previous research that provided a counter argument to Bruce's assertion that self and peer assessment strategies inflicted time constraints on teachers. This previous research suggested there are possible gains in time effectiveness to teachers as peer assessment processes can assist with judging large numbers of students. For example, an important role for self and peer assessment could be the ability to provide additional feedback from peers while allowing teachers to assess individual students less, but more effectively.

Vickerman (2009) found that the biggest problems with peer assessment all developed from potential inequities in peer assessors. This researcher attempted to alleviate some of this inequity by providing clear guidelines, modeling feedback and running three sessions, each with a different peer assessor.

In conclusion, there seemed to be substantial evidence to support the hypothesis that the implementation of project-based learning, supported by formative assessment and other assessment *for* learning strategies, would improve student comprehension and motivation in the secondary chemistry classroom.

IMPLEMENTATION

Class Description and Demographics

North Farmington High School is located in the city of Farmington Hills in Oakland County, Michigan. The school serves approximately 1300 students in grades nine through twelve. There are seventy classroom teachers and a student to teacher ratio of approximately 19 to 1.

Of the over 1300 students, one percent self identify as Hispanic, six percent as two or more races, eight percent as Asian/Pacific Islander, twenty one percent as black and sixty-three percent as white. Nineteen percent of students are eligible for free or reduced-price lunch ("North Farmington High School", 2013)

This research was implemented in a first trimester, general Chemistry course. This means the students were being introduced to the information for the first time. The class consisted of twenty-nine students in tenth, eleventh and twelfth grade. Of the twenty-nine students, seventeen were boys and twelve were girls. This was a co-taught section; there was a special education teacher in the room to assist with delivery and accommodation of materials. Ten students had individualized education plans, including one student who had a one-on-one paraprofessional.

All twenty-nine students and their parents were given consent forms (Appendix C) asking them to participate in the research. Of these twenty-nine students and parents, nineteen returned the forms and provided consent.

Project Description and Class Activities

For this project, students were asked to research the properties, atomic structure and common uses of a selected element or compound in order to answer the driving question: *How*

do the properties and/or structure of an element (or compound) impact how we use it?. The project was completed in three parts. In the first part, students selected an element, researched properties of their element and created used this information to create a virtual poster board called a Glogster. In the second part, students researched the atomic structure of their elements and demonstrated their understandings to the teacher using an info graphic called an Easel.ly. In the third part, students researched common uses of their elements and related these ideas to what they already knew about the properties and structures of their elements. Then they developed a video animation to teach their classmates what they had learned.

The project-based unit referenced here addressed three major Michigan Science Grade Level Content Expectations: C1.2 Scientific Reflection and Social Implications, C4.8 Atomic Structure and C4.9 Periodic Table. More specifically, the project addressed the following school generated learning targets: 1.3 I can label and describe the major groups of the periodic table, 2.5 I can create complete electron configurations for the first 36 elements and 2.6 I can create noble gas electron configurations for the first 36 elements. The professional learning team of Chemistry teachers at North Farmington High School had established these learning targets prior to development of this project. Table 1 details the implementation of the project and links each activity to a specific learning target.

Table 1 Project Implementation Schedule

DAY	LEARNING TARGET(S)	CLASS	**HOMEWORK**
Friday September 12 th	PBL Target: I can describe the requirements of the Element Portfolio Project.	Introduce Element Project- Entry Event (7 min) and Powtoon (2 min)	- Watch Weebly Tutorial Video on the link for ELEMENT PORTFOLIO PROJECT on my website. - Choose an element for research (and a 2nd choice)
Monday, September 15 th	PBL Target: I can create a website using Weebly.	- Discuss project-requirements for the Glogster - Create Weebly home page and add pages for each section of the project (Properties, Structure, Uses of Element)	- Watch Glogster Tutorial Video on my website. - Read Glogster Rubric in Project Packet
Tuesday, September 16 th	Content Target 1.3: I can use reliable internet resources to research the major groups of the periodic table.	- Discuss project-how to cite your sources. - Begin element research using the resources on my website.	Continue element research
Wednesday. September 17 th	Content Target 1.3: I can create a poster using Glogster to label and describe the major groups of the periodic table.	- Discuss rubric requirements for Glogster - Create Glogster to describe your element	

Table 1 (cont'd)			
Monday, September 22 nd	AfL Target: I can give helpful, specific and kind feedback to my peers	• Introduce Gallery Walk • Austin's Butterfly Video • Model peer feedback • Gallery Walk • Make changes to Glogster based on peer feedback	
Tuesday, September 23 rd	AfL Target: I can self assess my work based on specific criteria	• Complete self assessment and turn in project rubric for grading of Glogster • Turn in Weebly link to my shared drive turn in folder	
Thursday, October 2 nd			• Watch Easel.ly tutorial video on my website (under project link) • Read Easel.ly Rubric in Project Packets
Friday, October 3 rd	Content Targets 2.5 and 2.6: I can use Easel.ly to create BOTH complete and noble gas electron configurations	• Discuss Easel.ly project requirements • Start Easel.ly	• Continue work on Easel.ly configurations
Monday, October 6 th	PBL Target: I can link my Easel.ly to my weebly website.	• How to link Easel.ly to weebly website. • Finish Easel.ly	• Easel.ly must be linked to weebly website for Tuesday.

Table 1 (cont'd)			
Tuesday, October 7 th	AfL Target: I can give helpful, specific and kind feedback to my peers	- Review Peer Feedback Guidelines - Model Charlette with Easel.ly - Make changes to Easel.ly based on feedback	Easel.ly is due tomorrow
Wednesday, October 8 th	AfL Target: I can self assess my work based on specific criteria	Complete self assessment and turn in project rubric for grading of Easel.ly (you may resubmit Glogster rubric for re-grading with form)	

Thursday, October 9 th			Read Video/Animation Rubric in project packet and tips for good notes
Monday, October 13 th	Content Target 1.3: I can use a graphic organizer to take notes from an online source to research the major groups of the periodic table.	- Discuss Video/Animation project requirements - Introduce note taking tips and graphic organizer - Take notes from one source	If extension, finish taking notes from one source on my website.
Tuesday, October 14 th	Content Target 1.3: I can use a graphic organizer to take notes from an online source to research the major groups of the periodic table.	- Any questions about the graphic organizer or note taking?	Read and take notes from a second source

Table 1 (cont'd)			
Wed Oct 15- Fri Oct 24			Each night an additional source was assigned for note-taking
Friday, October 24 th			Finish taking notes on a total of 8 sources. The graphic organizer in your project packet should be complete to be prepared by Monday
Monday, October 27 th	PBL Target: I can answer the driving question <i>How do the properties and/or structure of an element (or compound) impact how we use it?</i>	- Review Video Rubric Requirements - Complete "Organizer for Video or Animation" to help you answer the driving question	Watch video tutorial on Powtoon or GoAnimate on my website
Tuesday, October 28 th	PBL Target: I can create a story board for a video presentation on the driving question	"Tech Blast" on Powtoon or GoAnimate - Complete a Powtoon or GoAnimate story board. - If time- begin work on your video presentation	Watch video tutorial on Powtoon or GoAnimate on my website
Wednesday, October 29 th	PBL Target: I can create a story board for a video presentation on the driving question	Continue work on storyboard or presentation	- Continue work on storyboard or video Video/Animation must be complete by Wednesday Nov. 5th

Table 1 (cont'd)			
Wednesday, November 5 th		Link video/animation to weebly	
Thursday, November 6 th	AfL Target: I can give helpful, specific and kind feedback to my peers	- Critical Friends Peer Instruction - Make changes or modifications to your video/animation	Video/Animations are due by Monday
Friday, November 7 th		Continue making modifications on your video presentation	Videos/Animations are due by Monday
Monday, November 10 th		Turn in Video/Animation Rubric to inbox	

Monday, November 17 th		All submitted Video/Animation Rubrics returned with feedback	
Thursday, November 20 th	PBL Target: I can reflect on the goals and outcomes of this project	Project Reflection (google doc on my website)	
Friday, November 21 st	PBL Target: I can share my video and website with my peers.	- Project Exhibition-canceled by student request. - Replaced with final exam review.	

On the first day of class, students completed a twenty-seven-item Chemistry A Pre-Test (Appendix D). Of the twenty-seven items, eighteen of these items were used in the analysis of the research-based unit discussed in this paper.

Students were introduced to the Element Portfolio Project in the second week of a twelve- week trimester. The teacher introduced the project with a short radio interview with parents of children affected by lead poisoning to demonstrate direct applications of studying an element. The students also analyzed a graph that showed a direct correlation between lead blood levels and incarceration for violent crime. Students then shared their reactions to the information.

The discussion was followed by a short cartoon animation introducing the basic guidelines and requirements for the project. Students were also given an Element Portfolio Project Packet (Appendix A) and instructed to keep the packet for the duration of the project. That night students were asked to watch a tutorial video introducing how to establish a website and they were also instructed to view a list of research topics and use this to choose two elements of interest for further learning.

The following day, students created their website homepages and added pages for each section of the project (properties, structure and uses of the element). In the second half of class students signed up for the elements they would research. For homework students were assigned to watch a tutorial video on how to make an online poster called a Glogster. They were also asked to read over the Glogster rubric in the Element Portfolio Project Packet.

After reviewing the Glogster rubric for homework, students were given the opportunity to ask clarifying questions. The teacher also provided whole group instruction on how to properly cite sources and showed the students that recommended sources for research on their chosen elements were provided on the classroom website. Students were instructed to use the remainder

of the class period to begin research on the properties and characteristics of their elements. Students were encouraged to continue their research as homework that evening. The researcher found that some students did continue this research independently, while others did not.

For the next two days, students were given independent work time to create a Glogster (online poster) describing the properties and characteristics of their selected element. At the end of the second day, a Thursday, the teacher demonstrated how to link the Glogster to the student websites. Students were required to finish any remaining work on the Glogster by the following Monday.

On Monday in class the teacher introduced the protocol for a peer feedback strategy called a Gallery Walk. Students viewed a short video clip called “Austin’s Butterfly” and were asked to reflect on what good peer feedback feels like and sounds like. The discussion of the video clip led to establishing a set of classroom norms for providing peer feedback. The whole class then practiced providing peer feedback using a Glogster created by a student from a previous year as an exemplar. Students spent approximately 15 minutes in the Gallery Walk providing written feedback to peers and another 15 minutes afterward reviewing the feedback they received and making changes and modifications to their work.

The following day students completed a self-assessment using the Glogster portion of the project rubric and then submitted the rubric for teacher feedback. After receiving teacher feedback along with an initial grade, students were encouraged to make changes to their project and re-submit the project for a re-grade.

For the nine days after submission of the Glogster, the topics of direct instruction included Bohr Diagrams, Dot Diagrams and electron configurations. Following this, students were assigned to watch a tutorial video on Easel.ly, a website for used for developing info

graphics. They were also asked to review the Easel.ly rubric in their Element Portfolio Project packets. The following day students were given an opportunity to ask clarifying questions about the Easel.ly requirements and were then given time to develop info graphics to describe the structure of their chosen element using Easel.ly. These info graphics were to contain both a complete and abbreviated electron configuration. Students had been introduced to electron configurations in the time between submission of the Glogster and introduction of the Easel.ly and so this allowed them to practice their newly acquired knowledge. Students were given two full class days to complete their Easel.ly info graphics and link them to their websites.

Once students had completed their Easel.ly's they were asked to review the peer feedback norms the class had already developed. Again, the whole class practiced providing feedback using an Easel.ly created by a former student. Then students were asked to find a partner and use a peer feedback protocol called a Charlette that was described in the project packet (Appendix A). Student spent approximately 20 minutes providing feedback to each other following the steps of the Charlette and then had another 10 minutes to reflect on the feedback they had received and make appropriate changes to their work.

The day after the Charlette, students completed a self-assessment using the Easel.ly portion of the project rubric included in the project packet (Appendix A) and then submitted their rubric for teacher feedback. After receiving teacher feedback and an initial grade, students were again encouraged to make changes to their project based on the feedback and re-submit the Easel.ly rubric for a re-grade.

The day after the Easel.ly info graphic was due, students were assigned to read the Video/Animation Rubric in the Element Portfolio Project Packet along with the sheet of tips for good note taking in the same packet.

The following day students were given the opportunity to ask clarifying questions of the Video/Animation Rubric and on good note-taking strategies. The teacher then introduced a graphic organizer provided in the project packet (Appendix A) and directed the students to use this as a tool to structure research on uses of their element or compound. The purpose of this graphic organizer was to help students to keep clear notes with referenced sources that would be easily accessible later in the project.

The teacher showed the students that 6-8 recommended resources (articles, websites and videos) for each research topic were provided on the class website (Appendix A). Students were encouraged to use these provided resources rather than finding their own. Students spent the remainder of the class period reading or listening to one of the resources and taking notes into the organizer.

The following day students were given an opportunity to ask clarifying questions about note taking on the provided organizer. That night they were assigned to read and take notes on a second source. Each night for the next six weekdays an additional source was assigned for note taking. Again, the researcher observed mixed results, with some students completing an additional source each night and others waiting until the last day to attempt to complete notes on all sources.

Once students had been given time to take notes on all eight provided sources, the teacher introduced one final organizer in the project packet (Appendix A). This organizer required students to go back to their Glogster online posters and Easel.ly info graphics and recall information they had shared about the properties, characteristics and structures of their chosen elements. The organizer then asked students to summarize what they had learned from their research. Finally, students were asked to synthesize all of these ideas in order to answer the

driving question: *How do the properties and/or structure of an element (or compound) impact how we use it?* Students also had to provide specific information from their research that supported this answer. The purpose of this second organizer was to scaffold the synthesis required of students by encouraging them to review information they had gathered in each part of the project before answering the driving question.

After completing this organizer, students were assigned to watch a video tutorial on either Powtoon or GoAnimate. These are both websites that allow the user to create animated videos.

The following day in class, the technology specialist came in and led students through an interactive presentation in which they practiced using both Powtoon and GoAnimate. He also used an exemplar to model for students how to plan an animated video using a storyboard. Students were asked to finish the storyboards that they started in class as homework.

Students were given two more class periods to create animations before participating in a final peer feedback strategy called a Critical Friends Protocol. In this protocol, the students work in groups of three and, following specific steps, watch and provide feedback on each other's animations. Following the peer feedback, students were given two more class periods and a weekend to finalize their animations.

On the day that the animations were due, students completed a final self-assessment and submitted their Video/Animation rubrics for teacher feedback. When students received their initial grade and feedback, they were again encouraged to make changes to their work and re-submit the rubric for a re-grade.

Three days after the students received teacher feedback on their animations they were asked to complete a project reflection (Appendix F). This consisted of nine short answer questions that students answered and submitted online using a Google Docs form.

The project exhibition was scheduled to occur the day after the project reflection. However, due to the number of students who had not completed the project, the students voted to use the time for final exam review rather than having an exhibition of work.

Five days after the students submitted their reflections they completed an eighty item final exam. Eighteen of the items on the final exam were identical to the items on the pre-test and were used as the post-test data (Appendix D).

RESULTS AND EVALUATION

A paired t-test was used to compare pre and post-test scores in order to check the effectiveness of project based learning in a high school chemistry classroom, which addressed periodic table trends and atomic structure. The test found $t(18) = 23.3496$, $p = 6.548 \times 10^{-15}$, with post-test scores associated with increased content knowledge compared to the pre-test scores.

Figure 1 Item Analysis of Pre-Test and Post-Test Responses

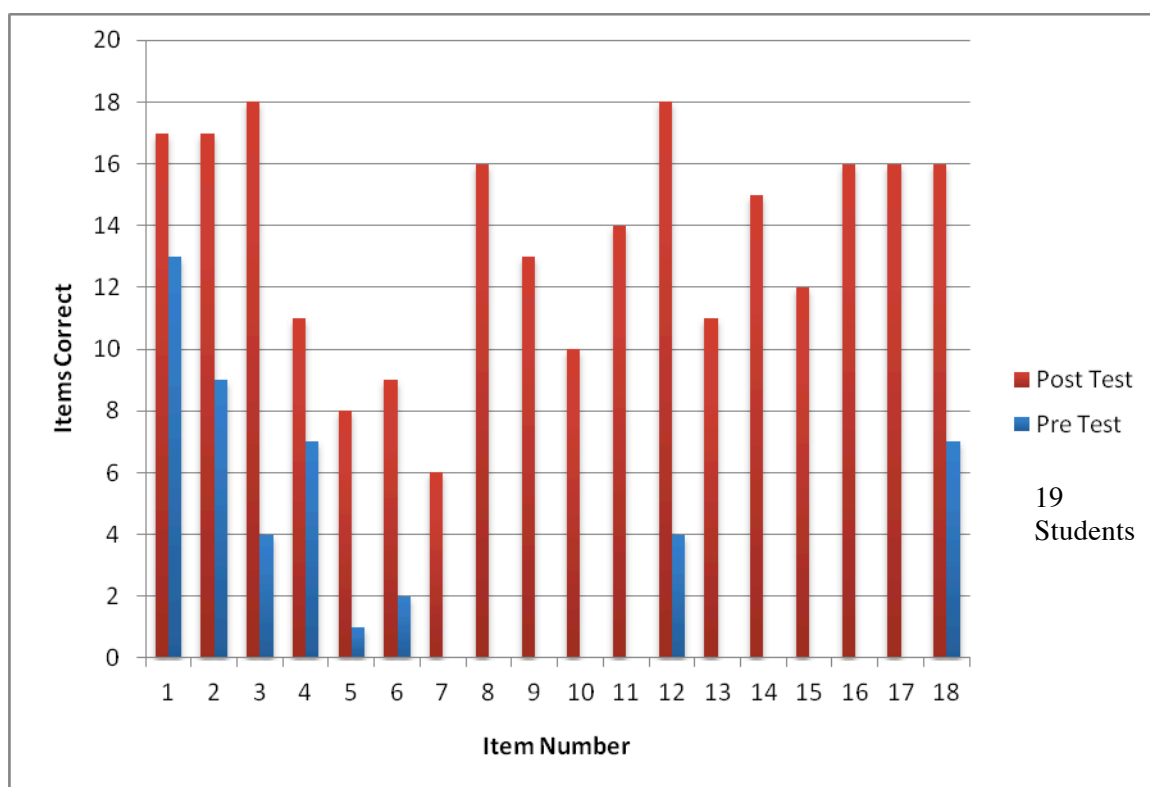


Figure 1 provides an eighteen-item analysis of correct answers on the pre-test and post-test.

The relatively high pre-test scores on items 1-6, 12 and 18 indicate that students started the course with knowledge of basic definitions of density, atomic number, isotopes and ions. They were also familiar with using the periodic table to identify the symbols to represent individual elements. The results of items 7-11 and 13-17 provide evidence that students did not bring any

prior knowledge of drawing diagrams of atomic structure such as Bohr diagrams, dot diagrams and electron configurations.

Figure 2 Pre- Test and Post-Test Mean Scores

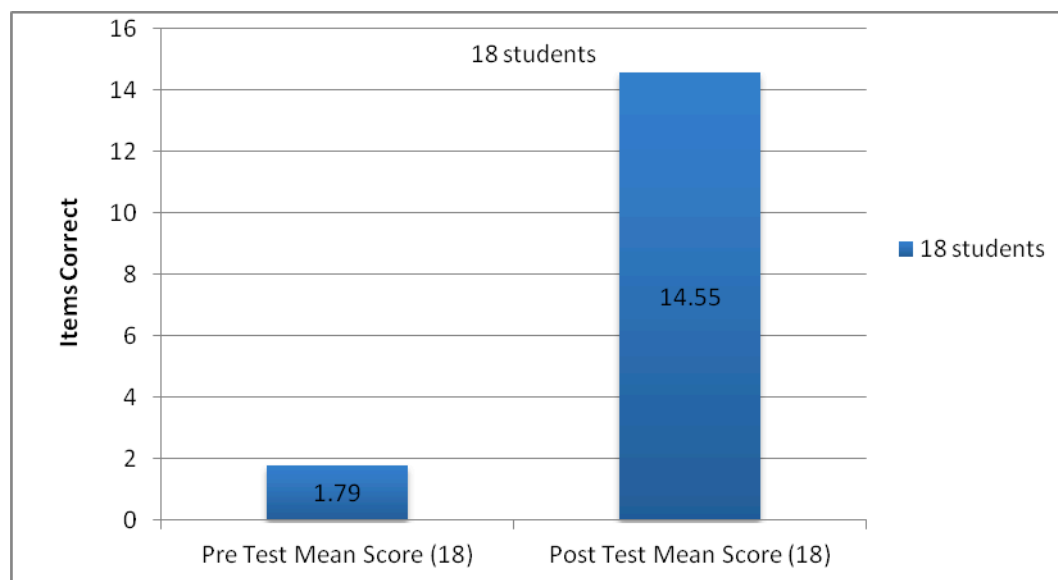


Figure 2 compares the mean score for the eighteen item pre-test and the post-test and shows a mean increase of 12.76 points from pre-test to post-test.

Table 2 Student Responses to Reflection Questions

Reflection Question	Positive Responses	Negative Responses	Abstained
Do you prefer this type of project based learning or more lecture based instruction and WHY?	13	4	0
Did having a choice in your project (choosing an element and a presentation style) make the project more enjoyable? WHY or WHY NOT?	13	3	1
Did using digital presentations make the project more enjoyable? WHY or WHY NOT?	9	6	2

Table 2 reports the number of positive (affirmative) statements for questions seven, eight and nine on the project reflection (Appendix F) that students completed at the end of the project. Seventeen student responses were recorded and evaluated.

This table indicates that, in general, students preferred project based learn to lecture based instruction. It also suggests that providing students with choice of element and presentation style makes the project more enjoyable. Although the majority of students appeared to enjoy using digital presentations, there were also a number of students who did not find this format enjoyable.

DISCUSSION AND CONCLUSION

Project Based Learning

This project could be evaluated on the six A's discussed in the article by Lattimer and Riordan (2011). The project met the standard of *academic rigor* because it addressed three standards and three learning targets for the course and was not introduced as an afterthought of learning, but integrated into the initial learning of the material. Students also learned specific technology based skills and practiced with web-based programs. The project was *authentic* because students researched the applications of a specific element or compound, which they selected based on interest. The project incorporated *applied learning* because students had to problem solve and communicate about creating their presentations during peer feedback. *Active exploration* was addressed as students developed a website that could be used by anyone in the world. *Assessment practices* were intended to involve an exhibition style presentation of student work to a public audience, although that did not occur due to time constraints. The only "A" that the project was missing was *adult connections*. It is possible that, time permitting, in the future community members could be invited to participate in a project exhibition.

The project could also be measured by what Larmer and Mergendoller (2010) summarized as the requirements of projects developed specifically for PBL in the article "7 Essentials of Project Based Learning". The defining characteristic of these projects was that they must center on a driving question. The driving question for this project was "How do the properties and structures of elements affect how we use them?". This was a high level question because it required students to synthesize information about both properties and structure and to connect those ideas to information on how we use a particular element. The type of synthesis question used in this project promoted the in-depth inquiry requirement of PBL because students

could not find the answer to their question directly through research. Instead, they had to use critical thinking to develop their own answer to the question.

This project also required students to develop both a webpage and a video to share information about the properties, structure and use of their element. As they did this, students communicated and collaborated in peer feedback protocols (the Gallery Walk, Charlette and Critical Friends Protocols) in order to generate and respond to peer feedback. According to Larmer and Mergendoeller (ibid), use of the 21st century competencies of communication, collaboration, critical thinking and creativity was another requirement of PBL.

The intention of this project was that once students had critiqued and revised their work, they would present their findings and answer to their driving question to an audience of peers, staff members, administrators and parents in an exhibit format. Due to lack of student readiness, this did not occur. Larmer and Mergendoeller stated that proponents of PBL claim “Schoolwork is more meaningful when it’s not done only for the teacher or the test. When students present their work to a real audience, they care more about its quality”. Larmer’s study found that both the peer group audience and the variety of opportunities for choice in both topic of research and design of product increased student motivation. In the current study, many students expressed increased motivation. For example, in the project reflection submitted on the last day of the project a student who had researched the use of lithium in the treatment of bipolar disorder explained: “I actually really enjoyed this project. Not only because I love learning about various mental illnesses in this world, but it also gave us the freedom to let our minds run free and express our elements in ways we like”. Another student shared that “being able to choose my element made me enjoy the project a lot more” adding “It kept me interested in the project”. A third student felt that “by you being able to choice (sic) you got to research something you were

curies (sic) about or wanted to know more about”. Of the seventeen students who completed a project reflection, thirteen felt that having a choice of element and presentation format made the project more enjoyable (Table 2).

In the Zhenyu (2012) study, students generally enjoyed the experience using the web page editor to present the project and reported feelings of engagement, concentration, confidence and success. However, some students experienced feelings of frustration and failure, especially when they encountered obstacles in using the technology. This was also true in the current study. In the project reflection nine out of seventeen students (Table 2) felt using digital tools made the project more enjoyable and made comments such as “Yes, to me it is [more enjoyable to use digital tools] because I like working with computers and electronics” and “It was fun trying different things and learning different things”. On the other hand, six of the seventeen responding students (Table 2) felt it made the project less enjoyable and made comments such as “I had a harder time because I am not used to using these websites” and “I’m very old-fashioned I like to do things the plain and simple way like writing on a piece of paper”.

The Zhenyu (ibid) study highlighted the challenges of providing students complete freedom in choosing a research project and recommended a more scaffolded project design. In the current research, students were instructed to choose from a list of potential topics based on interest and difficulty level. The students were then provided with a list of suggested resources. This certainly reduced frustration and saved time; however, it did not provide students with the opportunity to practice analyzing the relevance and credibility of sources.

The most positive feedback provided by the teachers in the Zhenyu (ibid) study, was the benefit of having a public audience for the student exhibition of work. However, the researchers felt that this experience would have been enhanced if the student rubric had included an

evaluation of the presentations. Due to time constraints, the current study did not include presentation evaluation. In the future, it would be interesting to invite other staff members, administrators and parents to assist in evaluation using a rubric on the day of the exhibition.

Martinez and de Pablo (2011) also emphasized the value of rubrics in grading and for use during formative assessment in their research on the implementation of PBL to teach about power supplies and photovoltaic electricity. In the Martinez and de Pablo study, students had to develop several intermediate and final deliverables. Not only the final result, but also the intermediate results were required to be submitted in order for the teacher to provide feedback to students on the degree to which they had met the project objectives. The work of Martinez and de Pablo (ibid) inspired the development of a series of three intermediates for the current project: a Glogster poster on element properties, an Easel-ly model of atomic structure and a video addressing use of the element and the answer to the driving question. Shortly before the submission of each of these intermediates the students participated in specific protocols for peer feedback as discussed in the implementation portion of this paper. One student felt that “the peer editing helped...by giving me feedback that showed me what I might have overlooked”. Another student explained “I got feedback on making my project more creative and it really helped because it helped me be more creative with all my other projects”. On the other hand, there were a few students who did not find the peer feedback to be useful. One of these students felt “the feedback wasn't really that helpful cause I think people aren't really gonna (sic) take the time to write down stuff to help you”.

Martinez and de Pablo (ibid) discussed the pros and cons of holistic rubrics, which evaluate the full work of a student without dividing it into components and analytical rubrics, which divide the work into a number of components and evaluate each those parts. The use of an

analytical rubric in this project allowed students to receive specific feedback on each of the intermediates before final project submission. One student reported: “The feedback I got was good little things like add more pictures or more details and they help (sic) my grade go up”. Another felt the rubric made the project more enjoyable: “I did enjoy this project because we were told exactly what to research and exactly how it should look”.

In terms of learning strategies, students in the Stefano et al (2013) PBL classroom reported greater use of elaboration, meta-cognitive self-regulation strategies, critical thinking, effort regulation and peer learning than their peer in the lecture based instructional setting. This confirmed findings from the Lam et al. (2009) study and was also reflected in the comments of students in the current study. One student described learning self-regulation when he said “Time management is something I needed the most, I improved it by moving physically away from distractions”. Another student described effort regulation: “You have to have patients (sic) because it usually took awhile trying to find the right answers. You also have to have good researching skills because you have to look through many articles to find the answer”. Of the seventeen students that submitted a self-reflection, thirteen said they preferred project-based learning to more traditional lecture based learning (Table 2). Of the four students who said they preferred lecture based learning, three specifically identified self-regulation as a challenge in project based learning by making statements such as “I prefer the other way because I (sic) not very responsible”. Not surprisingly, these three students were among those not prepared to present on the scheduled exhibition day.

Stefano et al. (ibid) collaborated with two instructors of applied disciplines and one educational psychologist at two private universities in the United States. They collected data from six courses totaling seventy-seven undergraduate students over two years. Two courses

implemented problem-based learning, while four courses used the related strategy of project-based learning. The major difference between the two strategies was that problem-based learning challenged students to solve a problem, while project-based learning required students to answer a question. The results of this study suggested that although both strategies promoted self-regulated learning, students using project-based learning reported higher levels of elaboration, critical thinking and meta-cognitive self-regulation. For this reason, the current research focused on project-based learning, although it would be beneficial to explore problem-based learning in the future in order to address the engineering practices of the Next Generation Science Standards.

In student reflections, it was clear that the students were aware of the higher levels of elaboration, critical thinking and self-regulation required in this project. Students made comments such as “I do prefer the project [to lectured based learning], it teaches students to use their time to the best of their ability and be independent” and “you need to have good researching skills, creativity, lots of critical thinking and you need to be very good at managing your time”.

Many of the student comments reflect feelings of frustration caused by the higher-level thinking required of the project. Some students felt they were not prepared for the challenges of the project. On the other hand, some students felt this project helped them to think differently about ideas presented in class. One student noted “This...learning is easier because I'm a visual learner”. The study by Barak and Dori (2005) discussed the use of project-based learning in the undergraduate science classroom as opposed to the secondary classroom; however, the similarities between their project and the current project were remarkable. Barak and Dori (ibid) acknowledged the findings of previous research, which established that difficulties in learning chemistry are attributed mainly to its abstract, unobservable, particulate basis. They also noted

that several researchers suggested using concrete models to help students visualize the particulate nature of matter. They claimed that computer graphics (specifically computerized molecular modeling) had been found to improve understanding of molecular 3D structure and therefore promoted meaningful learning in chemistry courses. The student reflections of the benefit of this project for visual learners appeared to support the conclusions of Barak and Dori (ibid).

The current project incorporated computer modeling of atomic structure and had a remarkably similar project design to that of Barak and Dori (ibid) with similar results. These results support the assertion that secondary students' understanding of chemistry was improved through the use of Internet research and computer modeling.

A major challenge to the implementation of project based learning was the time constraints that existed in a one trimester course and whether or not there was time to cover all required material while also incorporating all the elements essential to project-based learning including research, peer assessment, teacher feedback, revision and presentation of product to a public audience. Kunberger (2013) addressed this concern, but found that there was value to emphasizing depth over breadth. The significant improvement from pre-test to post test in the current study (Figure 1) would support Kunberger's conclusion, since students appeared to improve their understanding of core chemistry concepts while participating in project based learning. There was also evidence that the students appreciated the value of application through comments such as "we were supposed to accomplish the project by understanding our element and being able to understand the big picture". Another student enjoyed the opportunity to "learn about an element and find out how it helps us in everyday (sic) lives".

In Kunberger's (ibid) study the course was taught again after data collection, and the instructor made only a few modifications. One change was to make the optional reflective piece

at the end of the project into a required piece to “compel students to link course activities with professional skills valued in the workforce”. In the current study, the instructor required a project reflection at the end of the project in order to promote consolidation of skills and content knowledge and therefore improve retention of valuable information.

The findings of the study reported here support the previous findings of numerous researchers. The statistically significant difference in pre and post-test scores suggests that project based learning can support content learning in the high school chemistry classroom. Student reflections suggest that project based learning also challenges students to use skills such as self-regulation, critical thinking and meta-cognition in order to complete the required tasks.

Chun-Ming et al (2012) note a few limitations of their study, which the current study may serve to resolve. First, the findings were from an experiment on an elementary school science course; therefore, it could be difficult to generalize the findings to other courses or subjects. Secondly, more studies are needed to investigate the effectiveness of using other software with more flexible functions.

Chun-Ming et al (ibid) also discussed that it would be interesting to investigate the learning performance of students with different cognitive or learning styles. The current research was implemented in a co-taught classroom with students at a variety of levels, including students with diagnosed learning disabilities.

Subjective impressions of special education student performance indicated that this project did increase motivation for students who were not successful with more traditional learning styles. However, the reading level of some of the materials was challenging for a number of the special education students. These students also generally struggled with the time management required for successful completion of this project.

Although there were a number of aforementioned challenges with the project-based learning format of this unit, it is also clear that there were large gains made in science content knowledge during the unit. Figure 2 shows that the mean post-test score showed an increase of 12.76 points from the mean pre-test score. This is a significant improvement and suggests that although some students did not take full advantage of the learning experience, meaningful learning did occur. Figure 1 further illustrates that the largest gains were made on questions seven through eleven and thirteen through seventeen. These are items that relate to atomic structure, which is a topic that is not introduced in previous science courses. Items one through six along with item twelve ask students about the structure of the periodic table. Although there were still demonstrated gains on these items from the pre-test to the post-test, these gains were smaller. This is likely because this information has been introduced in previous courses and so many students enter the course with a basic knowledge of these topics.

Assessment for Learning

Newby and Winterbottom (2011) described an intersection between PBL and AfL in their study that explored the use of research homework as a way to integrate AfL practices within secondary science lessons. The study sought to describe how students' learning could be supported through the use of AfL strategies within research homework. They reported that although the self and peer assessment did appear to improve quality of work, more time could have improved the ability of students to effectively provide feedback. In the current project, additional time was allotted to teach specific feedback protocols to students. Although some students felt that this time was beneficial, the researcher noticed that many students were not fully engaged during peer feedback activities. In addition, school policies not allowing grade reduction for late submission of work prevented enforcement of strict deadlines. As a result, at

the scheduled time for the final peer assessment protocol, only six of the twenty-nine students had a product ready to share with their peers. In the future, consequences for not having work to share in the peer assessment would improve efficacy. For example, if a student did not have work to share at the time of peer assessment, that student might forfeit the right to resubmit work for a re-grade after receiving teacher feedback.

In the current study, the students who were prepared for the peer assessment protocols consistently reported that the feedback was helpful. In her study of effective self-assessment, Bruce (2001) made several recommendations for successful implementation of criteria-oriented self-assessment. Bruce emphasized the importance of explicitly teaching students how to self-assess and peer assess through the use of exemplars. Based on this recommendation, in the current study the researcher used previous student projects as examples and led the entire class through a peer-assessment of these projects before asking individual students to perform either self or peer assessments.

The teacher researcher also showed a short video clip of other students performing peer assessments and asked the class to create group norms to follow during peer feedback. One student referenced these norms in his reflection on feedback saying “We received very supportive and nice feedback from both teachers and students and we made sure not to criticize peoples (sic) projects”.

Bruce (ibid) found that students particularly enjoyed being involved in developing the rubric, because it helped them to clarify the expectations of the assignment. Although this was not part of the current project, it could be incorporated in the future.

Vickerman (2009) found the majority of students self-reported that peer assessment enhanced their learning; however, there was a significant group that did not report enhanced

learning from peer assessment. Differences in learning styles provided one argument for using a combination of self, peer and teacher feedback during PBL. She also concluded that peer-assessment not only improved the quality of the work at hand, but could also help students improve skills such as communication and critical thinking. Communication and critical thinking were two of the 21st century competencies promoted in PBL. In the current project, there were a variety of student responses to the self, peer and teacher assessment. Some students were very motivated to prepare their projects for the peer assessment activities and to provide quality feedback to their peers. Other students did not have a draft of their project prepared and therefore did not benefit from peer assessment. The majority of students reported during reflection that both the peer and teacher feedback were helpful for improving the quality of their final product.

In conclusion, the subjective observations and objective data of this researcher (a classroom teacher of six years) support the conclusion that a combination of self-assessment, peer-assessment and teacher feedback improves the quality of student projects. Self and peer assessment also provide an opportunity for students to engage in critical thinking and practice communication, which supports one of the major goals of project based learning.

Conclusion

The results of this study support the hypothesis that the use of project based learning will improve student understanding in the secondary science classroom. However, more work needs to be done to address the issue of intrinsic student motivation. Despite the fact that the majority of students reported a preference for project based learning over lecture based learning and reported that having choice in element and presentation format made the project more enjoyable, many students did not take advantage of re-grade opportunities or did not submit one or more

portions of the project at all. One student reflected, “This was a pretty cool project. I wish I had done more with it”.

It is possible that with a change in the school wide late work and homework policy, students would be more inclined to observe teacher imposed deadlines and would therefore be less overwhelmed by the scope of the project. This could improve motivation and increase the number of students taking advantage of re-grade opportunities. Without a change in the school policy, the classroom teacher may also choose to limit the scope of the project by having students report the characteristics and properties of their chosen elements directly onto the website rather than using the online Glogster poster.

Either of these changes would be worth exploring in order to improve upon this project and allow for the continued implementation of project based learning in the secondary science classroom.

APPENDICES

Appendix A

Element Portfolio Project Packet

Element Portfolio Project

Driving Question “How do the properties and/or structure of an element (or compound) impact
how we use it?”

The Element Portfolio Project

Purpose:

To create a website “portfolio” about an element that answers the driving question, “How do the properties and/or structure of an element (or compound) impact how we use it?”. You will add to this portfolio throughout our units on the periodic table, atomic structure and compounds. Near the end of the trimester you will share your findings in an exhibition style presentation.

Guidelines:

1. For this project you must work individually.
 - You will periodically be placed in groups for feedback and peer evaluation.
2. Choose an element that you will focus on all trimester (think backwards by looking at the presentation topics listed in this packet).
 - The element must one of the first 36 elements listed on the periodic table.
 - In other words, in one of the first four rows or no larger than Krypton.

Requirements:

1. Create a description of your element using Glogster, a free website that creates interactive posters.
 - Find resources for your project on Mrs. Crane’s website
 - You must use at least 2 of the provided resources
 - Include the following in your description:
 - Word description of element:
 - What group or “family” does your element belong to? (alkali metals, halogens etc.)
 - Physical characteristics-color, hard/soft, lustrous/dull, brittle/malleable, reactive/non-reactive, metal/metalloid/nonmetal etc.
 - Visual description of element:
 - A picture of your element.
 - The chemical symbol of your element with the mass and atomic number labeled
 - You must cite (give credit to) any articles or website you use for information or pictures.
 - Once you have created your Glogster, you will create a Weebly website and put a link to your Glogster on your Weebly.

2. Create electron configurations (complete AND abbreviated) of your element using Easel.ly, a free online tool for creating visuals, and include a link to it on your Weebly website.
 - CLEARLY LABEL: the chemical symbol, mass, atomic number, all 3 parts of the configuration and the noble gas of the abbreviated configuration.
 - Do not forget to include BOTH complete AND abbreviated configurations.
3. Create a video or animation that explains one way we use your element (or a compound of your element)
 - Research your element/compound:
 - Find resources for your project on Mrs. Crane's website- You should use as many as possible.
 - Use the graphic organizer provided to organize your research.
 - Put together ideas from multiple articles and apply those ideas in order to **answer the driving question** "*How do the properties and/or structure of an element (or compound) impact how we use it?*"
 - Prepare your video or animation using digital tools:
 - Utilize *at least* 1 of the following tools in your presentation
 - GoAnimate- create animated videos (we have a school license for this)
 - Pixton- digital comic strip maker (free)
 - Powtoon- animated videos and presentations (free version available)
 - You are welcome to use a tool not listed but *please ask for approval before starting*
 - Tips for a good video
 - Read or watch as many of the provided sources as possible to get a full understanding of your element/compound and how it is used.
 - Put the ideas from the sources in your own words- otherwise it will be confusing for your classmates and is considered plagiarizing!
 - Citation of all sources used (give credit to the articles or websites you used)
 - If you include a picture or video clip must have a caption underneath summarizing the important ideas. You might choose to only show certain parts of a video if it is long.

- **Answer the driving question: “How do the properties and/or structure of an element (or compound) impact our daily lives?”**
4. Each student must submit a reflection based on your topic and how you put your project together. You will find the reflection questions in an online document linked on the bottom of the project page of on website.
 5. This project will be worth 60 points and will be based on the attached rubric.

EXTRA CHALLENGE OPTIONS:

Create a Bohr diagram of your element using Easel.ly, a free online tool for creating visuals, and include a link to it on your Weebly website.

- **CLEARLY LABEL:** the nucleus, shells, protons, neutrons and electrons (with arrows or a key).

Create Lewis dot diagrams for the atom AND ion of your element using Easel.ly, a free online tool for creating visuals, and include a link to it on your Weebly website.

- The ion diagram must include brackets and a charge written as a superscript.
- The Easel.ly must explain what the dots represent and if the ion is a cation or an anion

Topics for your Video or Animation

This will be the last part of your Element Portfolio Project, but you should use this to determine which element you will start investigating

Hydrogen explosions at Nuclear Power Plants (Chernobyl, Three Mile Island and Fukushima) (Red)

<http://www.powermag.com/lessons-learned-from-a-hydrogen-explosion/>
<http://www.whatisnuclear.com/articles/nucenergy.html>
<http://www.iaea.org/newscenter/features/chernobyl-15/chno-faq.shtml>
<http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/chernobyl-bg.html>
<http://www.whatisnuclear.com/chernobyl/>
<http://www.scientificamerican.com/article/partial-meltdowns-hydrogen-explosions-at-fukushima-nuclear-power-plant/>
<http://www.forbes.com/2011/03/16/japan-disaster-nuclear-opinions-roubini-economics.html>

Hydrogen Fuel Cells (and their new scandium storage systems) (Yellow)

<http://www.renewableenergyworld.com/rea/tech/hydrogen>
<http://energy.gov/eere/videos/energy-101-fuel-cell-technology>
<http://energy.gov/eere/fuelcells/fuel-cells-basics>
<http://energy.gov/eere/fuelcells/fuel-cell-animation>
http://www.fchea.org/core/import/PDFs/factsheets/The%20Hydrogen%20Economy_NE_W.pdf
<http://environment.nationalgeographic.com/environment/global-warming/fuel-cell-profile/>
<http://www.theaureport.com/pub/na/richard-karn-australian-scandium-could-create-new-market>
<http://www.greentechmedia.com/articles/read/the-fuel-cell-to-beat-all-fuel-cells>

Why helium makes balloons float and voices high (Green)

https://www.youtube.com/watch?v=kE8I_M2pyg8
<http://video.xin.msn.com/watch/video/webisode-10-gases/1pbuw2x0w>
<https://www.youtube.com/watch?v=7iR6vfX0Lpg>
<http://www.howstuffworks.com/helium1.htm>
https://www.youtube.com/watch?v=5o58_1puJn8
<http://www.scientificamerican.com/article/why-does-inhaling-helium/>
<http://mentalfloss.com/article/21590/why-does-inhaling-helium-make-your-voice-sound-funny>
<http://chemistry.about.com/od/demonstrationexperiments/a/sulfurfluoride.htm>
<https://www.youtube.com/watch?v=u19QfJWI1oQ>
<http://www.thenakedscientists.com/HTML/podcasts/scrapbook/show/2010.12.25/>

Beryllium for engineering satellites (Yellow)

<http://science.howstuffworks.com/satellite.htm>

<http://www.sciencechannel.com/tv-shows/how-do-they-do-it/videos/how-do-they-do-it-space-satellites.htm>
http://www.ucsusa.org/nuclear_weapons_and_global_security/solutions/space-weapons/what-are-satellites-used-for.html
<http://materion.com/Markets/DefenseandScience/SpaceScienceandAstronomy/SpaceStructuresandSatellites.aspx>
<http://materion.com/~media/Files/PDFs/Beryllium/AlBeMet%20Materials/Use%20of%20Aluminum-Beryllium%20Composites%20on%20the%20ORBCOMM%20Satellite.pdf>

Pentaborine “zip fuels” for rockets during the Cold War (Yellow)

<http://www.jfklibrary.org/JFK/JFK-in-History/The-Cold-War.aspx>
<http://www.britannica.com/EBchecked/topic/125110/Cold-War>
<https://medium.com/war-is-boring/the-strange-history-of-sci-fi-super-fuels-cd72a6219947>
http://www.unrealaircraft.com/notes_fuel.php
<http://www.borax.com/library/articles/news-and-events/news-release/from-missiles-to-medicine>
<http://aviationtrivia.blogspot.com/2010/09/boron-based-high-energy-jet-fuels.html>
http://books.google.com/books?id=Sy0DAAAAMBAJ&pg=PA86&lpg=PA86&dq=zip+fuels&source=bl&ots=gXI0YhVRxD&sig=gd4P1S4viUWNY0x_Oa6nQc5LG_Y&hl=en&sa=X&ei=WhWjU77bOs-syATXhIGIAQ&ved=0CHYQ6AEwBw#v=onepage&q=zip%20fuels&f=false (pages 86-89 and then page 250)
<http://www.scribd.com/doc/15062569/Pentaborane-Taming-the-Dragon-pdf>

Lithium in the treatment of bipolar disorder (Red)

<http://www.nimh.nih.gov/health/publications/bipolar-disorder-in-adults/index.shtml#pub1>
<http://health.howstuffworks.com/mental-health/depression/facts/the-chemical-connection-to-depression.htm>
<http://depression.about.com/cs/brainchem101/a/brainchemistry.htm>
<http://scienceblogs.com/retrospectacle/2006/09/06/how-does-lithium-act-as-an-ant/>
<http://psychcentral.com/lib/mood-stabilizers-for-bipolar-disorder/00059>
<http://www.bipolarbrain.com/lithium.html>
<http://www.cchr.org/sites/default/files/education/mood-stabilizers-booklet.pdf> (warning: this is a very one-sided argument against the use of medication to treat mental disorders, so use your best critical thinking skills!)
<http://itech.fgcu.edu/&/issues/vol2/issue1/bipolar.htm>
http://www.chem.uwec.edu/Chem115_F00/mauelec/research.htm

Carbon in gasoline- combustion, octane rating, hydrocarbons (Yellow)

<http://science.howstuffworks.com/gasoline.htm>
<http://www.autoshop101.com/forms/h55.pdf>
<http://www.intel.com/content/dam/www/program/education/us/en/documents/project-design/react/react-presentation.pdf>
<https://www.youtube.com/watch?v=zEjEqnMBdEM>

https://www.youtube.com/watch?v=_wzJQF1k9I
<http://assets.slate.wvu.edu/resources/1117/1308082357.gif>
http://earthguide.ucsd.edu/eoc/special_topics/teach/sp_climate_change/images/burning_gasoline.jpg

Carbon dioxide and methane as a green house gas

<https://www.youtube.com/watch?v=snYL5p2lUrY>
https://www.youtube.com/watch?v=BPJJM_hCFj0
<http://epa.gov/climatechange/ghgemissions/gases/ch4.html>
<http://www.epa.gov/climatechange/ghgemissions/gases/co2.html>
<http://climate.nasa.gov/effects/>
<http://www.nature.org/ourinitiatives/urgentissues/global-warming-climate-change/threats-impacts/> (be sure to click on each picture for more info)
<http://www.elmhurst.edu/~chm/vchembook/511natgascombust.html>
https://www.youtube.com/watch?v=_wzJQF1k9I

Nitrates and Nitrites in food preservation (Green)

http://fyi.uwex.edu/meats/files/2012/02/Nitrate-and-nitrite-in-cured-meat_10-18-2012.pdf
<http://www.livescience.com/36057-truth-nitrites-lunch-meat-preservatives.html>
<http://www.wnyc.org/story/190205-last-chance-foods-nitrate-debate/>
<http://www.livestrong.com/article/541308-fruits-vegetables-that-are-high-in-nitrates/>
http://www.nytimes.com/2007/04/04/dining/04curi.html?_r=0
<http://www.coopfoodstore.coop/news/good-or-bad-nitrates-and-nitrites-food>
<http://www.todayifoundout.com/index.php/2013/01/why-salt-preserves-meat/>
<http://www.southernnevadahealthdistrict.org/health-topics/botulism-foodborne.php>

Nitrogen compounds in acid rain formation (red)

<http://www.epa.gov/acidrain/what/index.html>
<http://www.epa.gov/acidrain/effects/index.html>
<http://www.epa.gov/acidrain/reducing/index.html>
<http://www.elmhurst.edu/~chm/vchembook/193nox.html>
<http://enviro.tropmet.res.in/menu/Pollutants/NOx.htm>
<http://www.epa.gov/acidrain/measure/ph.html>
<http://bqs.usgs.gov/acidrain/program.pdf>
<http://water.usgs.gov/nwc/NWC/pH/html/ph.html>

Nitrogen and Sulfur in food dyes such as Red Dye #40 (RED)

<http://www.efsa.europa.eu/en/efsajournal/pub/3234.htm>
<http://www.thelancet.com/journals/lancet/article/PIIS0140673607613063/abstract>
<http://www.red40.com>
<http://pubs.acs.org/cen/whatstuff/stuff/8134foodcoloring.html>
<http://pubchem.ncbi.nlm.nih.gov/rest/chemical/allura+red+ac+dye>
<http://www.rsc.org/chemistryworld/News/2008/April/11040804.asp>
<http://www.understandingfoodadditives.org/pages/ch2p1-2.htm>

Ozone (oxygen): Good up high, bad nearby (yellow)

<http://epa.gov/airquality/ozonepollution/pdfs/ozonegb.pdf>
<http://www.epa.gov/groundlevelozone/basic.html>
<http://www.lung.org/healthy-air/outdoor/resources/ozone.html>
<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1314964/>
<http://www.theozonehole.com/ozonecreation.htm>
<http://www.esrl.noaa.gov/csd/assessments/ozone/2010/twentyquestions/Q10.pdf>
<http://ozonewatch.gsfc.nasa.gov/facts/hole.html>
<http://uv.biospherical.com/student/page2.html>

Chloro-floro carbons banned as refridgerants (in air conditioning, refrigerators and industry) (yellow)

<http://www.ciesin.org/TG/OZ/cfcozn.html>
<http://www.esrl.noaa.gov/gmd/hats/publictn/elkins/cfcs.html>
<http://www.theozonehole.com/cfc.htm>
<http://www.epa.gov/ozone/defns.html>
http://www.epa.gov/ozone/science/sc_fact.html
<http://www.britannica.com/EBchecked/topic/113689/chlorofluorocarbon-CFC>
<http://www.sciencedaily.com/releases/2012/02/120224110737.htm>
http://www.ucsusa.org/global_warming/science_and_impacts/science/ozone-hole-and-gw-faq.html

Sodium chloride in water softeners (this also relates to calcium, magnesium and iron) (RED)

<http://www.popularmechanics.com/home/improvement/interior/1275126>
<http://home.howstuffworks.com/question991.htm>
<http://www.scientificamerican.com/article/how-do-water-softeners-wo/>
<http://www.steamcombustion.com/sitebuilder/images/qq1sgWaterSofteners-451x600.jpg>
<http://www.hamburg.mi.us/SODIUM%20CHLORIDE%20ISSUES/pdfs/deq-wmd-gwp-SodiumChlorideWaterSofteners.pdf>
<http://www.wqpmag.com/potassium-chloride-vs-sodium-chloride>
<http://www.wqpmag.com/removing-contaminants-chemistry>
<http://www.wqpmag.com/iron-water-supply>

Magnesium in chlorophyll and Iron in blood hemoglobin (RED)

http://www.phschool.com/science/biology_place/biocoach/photosynth/chlorophyll.html
http://www.chm.bris.ac.uk/motm/chlorophyll/chlorophyll_h.htm
<http://www.wisegeek.com/what-is-the-connection-between-chlorophyll-and-magnesium.htm>
<http://www.worldofmolecules.com/life/chlorophyll.htm>
<http://www.texasheartinstitute.org/HIC/anatomy/blood.cfm>
<https://www.youtube.com/watch?v=UhqcB34AwpU>
<http://chemed.chem.purdue.edu/genchem/topicreview/bp/1/biochem/blood3.html>
<http://we-are-star-stuff.tumblr.com/post/73244784812/eosinophillia-red-vs-green-the-similarities>

Why is steel used in the bodies of car and why is it starting to be replaced with aluminum? (RED)

<http://www.cartalk.com/blogs/jim-motavalli/steel-vs-aluminum-lightweight-wars-heat>
https://www.youtube.com/watch?v=kE8I_M2pyg8
<http://articles.latimes.com/2014/jan/17/business/la-fi-autos-weight-20140118>
<http://discoverykids.com/articles/how-is-steel-made-from-iron/>
<http://www.wenzelmetalspinning.com/steel-vs-aluminum.html>
http://advanceplastics.ca/product_images/uploaded_images/aluminum-vs-steel.jpg
<http://www.marketwatch.com/story/aluminum-in-autos-better-than-steel-to-save-energy-and-cut-carbon-oak-ridge-national-lab-confirms-2013-09-19> (this article argues for aluminum cars)
<http://www.worldautosteel.org/why-steel/safety/vehicle-safety-and-steel/> (this article argues for steel cars)

Why is it called Silicon Valley?: Silicon in computer chips and solar panels (YELLOW)

<http://www.britannica.com/EBchecked/topic/544409/Silicon-Valley>
<http://www.npr.org/2012/03/26/149404846/the-birth-of-silicon-valley>
<http://electronics.howstuffworks.com/diode.htm>
<http://curiosity.discovery.com/question/what-makes-silicon-good-semiconductor>
<http://www.dummies.com/how-to/content/electronics-basics-what-is-a-semiconductor.html>
<http://www.mse.umd.edu/whatismse/semiconductors>
<https://www.youtube.com/watch?v=aWVywhzuHnQ>
<http://science.howstuffworks.com/environmental/energy/solar-cell2.htm>

Phosphorus in fertilizers and animal waste affects water quality in lakes and rivers - YELLOW

<http://www.wisegeek.com/what-is-phosphorus-fertilizer.htm>
<http://www1.fipr.state.fl.us/PhosphatePrimer/0/8CEB80BB741B166585256F800077C38F>
<http://www.els.net/WileyCDA/ElsArticle/refId-a0003249.html>
http://www.unep.or.jp/ietc/publications/short_series/lakereservoirs-3/3.asp
<http://science.jrank.org/pages/5146/Phosphorus-Removal.html>
<http://www.sciencedaily.com/releases/2012/08/120815112243.htm>
<http://www.extension.umn.edu/agriculture/nutrient-management/phosphorus/understanding-phosphorus-fertilizers/>
http://water.epa.gov/polwaste/nps/success319/mi_poterfield.cfm

High sulfur coals in power plants produce acid rain- YELLOW

http://www.fossil.energy.gov/education/energylessons/coal/gen_howformed.html
http://www.fossil.energy.gov/education/energylessons/coal/gen_coal.html
http://www.ucsusa.org/clean_energy/coalvswind/brief_coal.html
https://www.nsf.gov/od/lpa/nsf50/nsfoutreach/htm/n50_z2/pages_z3/17_pg.htm#answer1
<http://online.wsj.com/news/articles/SB114583391429033632>
<http://www.epa.gov/acidrain/what/index.html>
<http://www.epa.gov/acidrain/effects/index.html>

<http://www.epa.gov/acidrain/measure/ph.html>

Chlorine gas in chemical warfare (WWI and Syria)- GREEN

<http://www.bt.cdc.gov/agent/chlorine/basics/facts.asp>

<http://spartacus-educational.com/FWWchlorine.htm>

<http://www.firstworldwar.com/weaponry/gas.htm>

<http://www.bris.ac.uk/Depts/Chemistry/MOTM/mustard/mustard.htm>

<http://www.cfr.org/iraq/mustard-gas/p9551>

<http://www.independent.co.uk/news/world/middle-east/syria-conflict-president-assads-forces-accused-of-using-chlorine-gas-against-rebels-despite-pledges-to-give-up-chemical-weapons-9550016.html> (WARNING: There are some disturbing pictures in this article)

<http://www.reuters.com/article/2014/05/23/us-syria-crisis-chlorine-idUSBREA4M08V20140523>

<http://www.bbc.com/news/world-middle-east-26116868> (WARNING: There are some disturbing pictures in this article)

Potassium perchlorate in fireworks (GREEN)

<http://pubs.acs.org/cen/whatstuff/stuff/7927sci3.html>

<http://chemistry.about.com/library/weekly/blfireworks.htm>

<http://chemistry.about.com/od/fireworkspyrotechnics/a/fireworkcolors.htm>

<http://chemistry.about.com/od/4thofjulychemistry/ss/How-Are-Colors-Formed-in-Fireworks.htm>

<http://chemistry.about.com/od/howthingswork/a/fireworks.htm>

<http://www.rsc.org/chemistryworld/podcast/CIEcompounds/transcripts/KClO3.asp>

<http://www.themarysue.com/learn-how-fireworks-happen/#geekosystem>

<http://www.bee-inc.com/blog/wp-content/uploads/2014/01/how-fireworks-work-infographic.jpg>

Calcium phosphate in foods to prevent osteoporosis (YELLOW)

http://www.niams.nih.gov/Health_Info/Bone/Bone_Health/

<http://www.endocrineweb.com/conditions/osteoporosis/osteoporosis-overview>

<http://www.endocrineweb.com/conditions/osteoporosis/role-calcium-vitamin-d-bone-health>

<http://nof.org/articles/886>

<http://www.livestrong.com/article/475373-what-is-calcium-phosphate/>

<http://www.hsph.harvard.edu/nutritionsource/vitamin-d/>

<https://www.bcm.edu/research/centers/childrens-nutrition-research-center/consumer/archives/calcium-fortified-cereal.htm>

<http://www.nutraceuticalsworld.com/blog/formulation/2013-07-18/calcium-fortification-challenges-benefits>

Calcium carbonate in shells and corals dissolving due to global warming (Yellow)

<http://www.epa.gov/climatechange/basics/>

http://water.epa.gov/type/oceb/habitat/coral_index.cfm

<http://humantouchofchemistry.com/colourful-seashells.htm>

<http://www.epa.gov/acidrain/measure/ph.html>
<http://centerforoceansolutions.org/climate/impacts/ocean-acidification/> (make sure to click on the picture links along with reading the text)
<http://centerforoceansolutions.org/climate/impacts/ocean-acidification/decalcification/>
<http://www.terrain.org/articles/21/burns.htm>
<http://theotherco2problem.wordpress.com/what-happens-chemically/>

Titanium Alloys: the new “in” metal for aircrafts and golf clubs (RED)

<https://www.youtube.com/watch?v=9LHDSB1n1lk>
<http://industrialtalks.wordpress.com/2012/12/12/why-titanium-is-used-in-the-aircraft-industry/>
<http://www.titaniumfortomorrow.com/tft/military.do> (text and video)
<http://www.golf-components.com/titanium.html>
<http://www.popsci.com/diy/article/2007-12/titanium-or-plain-ol-steel>
<http://www.nbclearn.com/science-of-golf>
https://www.youtube.com/watch?v=kE8I_M2pyg8 (scroll to the bottom of the page for the thumbnail of the video “science of golf: evolution of the golf club”, the important part starts around 3 minutes)
<http://thomas.pattman.net/physics/>

Lithium, Zinc or Manganese : How Different Types of Batteries Work (RED)

<http://www.qrg.northwestern.edu/projects/vss/docs/power/2-how-do-batteries-work.html>
https://www.youtube.com/watch?annotation_id=annotation_482751&feature=iv&src_vid=KkRwuM4S8BQ&v=gWKOjncBMCQ
<https://engineering.mit.edu/ask/how-does-battery-work>
<http://www.wisegeek.org/what-are-the-key-components-of-an-alkaline-battery.htm>
https://www.youtube.com/watch?v=P7tOipB_-38
<http://hyperphysics.phy-astr.gsu.edu/hbase/electric/leadacid.html>
<http://electronics.howstuffworks.com/everyday-tech/lithium-ion-battery.htm>
<http://www.brighthubengineering.com/power-generation-distribution/123909-types-of-batteries-and-their-applications/>

Cobalt for food irradiation (one isotope is radioactive) (RED)

http://www.epa.gov/rpdweb00/sources/food_irrad.html
<http://www.fda.gov/Food/ResourcesForYou/Consumers/ucm261680.htm>
<http://www.ndt-ed.org/EducationResources/CommunityCollege/RadiationSafety/theory/decay.htm>
<http://www.colorado.edu/physics/2000/isotopes/> (this has section that use JAVA applets that will not work on the chromebooks, so you may need to use a media center laptop or your home computer)
<http://uw-food-irradiation.engr.wisc.edu/Process.html>
<http://www.physics.isu.edu/radinf/food.htm>
<http://www.iaea.org/Publications/Booklets/foodirradiation.pdf> (this is a long article, so you might pick and choose which sections to read based on what you want to focus on in your project- also this is put out by a group that is in favor of food irradiation so it is quite one sided)

<http://www.organicconsumers.org/Irrad/irradfact.cfm> (this is put out by a group that is against food irradiation, so use your best critical thinking skills!)

Zinc oxide (and titanium dioxide) in sunscreen (green)

<http://www.loc.gov/rr/scitech/mysteries/sunscreen.html>
<http://www.physics.org/article-questions.asp?id=46>
<http://www.livescience.com/32666-how-does-sunscreen-work.html>
http://consults.blogs.nytimes.com/2009/06/10/what-to-look-for-in-a-sunscreen/?_php=true&_type=blogs&_r=0
<http://www.nytimes.com/2008/07/22/health/22well.html>
<http://www.ewg.org/2014sunscreen/the-trouble-with-sunscreen-chemicals/>
<http://www.cancercouncil.com.au/wp-content/uploads/2012/03/Sunscreen-information-sheet1.pdf>
<http://www.madehow.com/Volume-2/Sunscreen.html>

Gallium in thermometers instead of mercury- why it is better (YELLOW)

<https://www.youtube.com/watch?v=9LHDSB1n1k>
<http://www.chemistrylearner.com/galinstan.html#composition-of-galinstan-metal-alloy>
<http://sciencewithryan.blogspot.com/2014/03/23-galinstan-metal.html>
<http://www.farmersalmanac.com/weather/2010/11/22/how-does-a-thermometer-work/>
<http://curiosity.discovery.com/question/how-do-thermometers-measure-temperature> (also watch the video at the bottom)
<http://www.scientificamerican.com/article/jeremy-piven-mercury-poisoning/> (scroll past the discussion of Jeremy Piven to get to the science of mercury poisoning)
http://www.naturalnews.com/016544_mercury_heavy_metals.html
https://www.youtube.com/watch?v=JzJQQ_PbBhw

Arsenic in Rice (YELLOW)

http://toxtown.nlm.nih.gov/text_version/chemicals.php?id=3
<http://www.fda.gov/food/foodborneillnesscontaminants/metals/ucm319870.htm>
http://well.blogs.nytimes.com/2014/04/18/the-trouble-with-rice/?_php=true&_type=blogs&_r=0
<http://grist.org/food/theres-arsenic-in-your-rice-and-heres-how-it-got-there/> (make sure to click on the infographic also)
<http://www.cotton.org/tech/pest/bollweevil/eradication2.cfm>
<http://www.auburn.edu/~dunnmes/whatisabollweevil.html>
<http://blogs.plos.org/speakeasyscience/2012/02/21/on-rice-and-arsenic/>
<http://consumerreports.org/cro/magazine/2012/11/arsenic-in-your-food/index.htm>

Bromine in flame retardants and Mountain Dew (YELLOW)

<http://www.bromine-info.org/en/are-brfs-safe/why-is-bromine-effective-as-a-flame-retardant/>
<http://www.bsef.com/infographic-brominated-flame-retardants-an-essential-part-of-modern-life>
<http://www.nachi.org/brominated-fire-retardant-dangers.htm>
<http://www2.buildinggreen.com/article/flame-retardants-under-fire>
<http://www.environmentalhealthnews.org/ehs/news/2011/brominated-battle-in-sodas>

<http://www.usatoday.com/story/news/nation/2014/05/05/coke-pepsi-dropping-bvo-from-all-drinks/8736657/>
<http://www.scientificamerican.com/article/what-chemicals-are-used-i/>

Topics for your Video or Animation- Organized By Difficulty

This will be the last part of your Element Project, but you should use this to determine which element you will start investigating

RED- High Difficulty Level

Hydrogen explosions at Nuclear Power Plants (Chernobyl, Three Mile Island and Fukushima)

Lithium in the treatment of bipolar disorder

Nitrogen compounds in acid rain formation

Nitrogen and Sulfur in food dyes such as Red Dye #40

Sodium chloride in water softeners

Magnesium in chlorophyll and Iron in blood hemoglobin

Lithium, Zinc or Manganese: How Different Types of Batteries Work

Cobalt for food irradiation

YELLOW- Medium Difficulty Level

Hydrogen Fuel Cells (and their new scandium storage systems)

Beryllium for engineering satellites

Borine in Pentaborine rocket “zip fuels” during the Cold War

Carbon in Gasoline

Oxygen in ozone: Good up high, bad nearby

Chloro-floro carbons and the ozone hole

Why is it called Silicon Valley? Silicon in computer chips and solar panels

Environmental concerns of Phosphorus in fertilizers

High sulfur coals in power plants produce acid rain

Calcium phosphate in foods to prevent osteoporosis

Calcium carbonate in shells and corals dissolving due to global warming

Gallium vs. Mercury Thermometers

Arsenic in Rice

Bromine in flame-retardants and Mountain Dew

GREEN- Low Difficulty Level

Why helium makes balloons float and voices high

Carbon in The Greenhouse Gases and Climate Change

Nitrates and Nitrites in food preservation

Aluminum vs. Steel in the bodies of cars

Chlorine gas in chemical warfare (WWI and Syria)- warning, this can be disturbing

Potassium perchlorate in fireworks

Titanium Alloys: the new “in” metal for aircrafts and golf clubs

Zinc oxide (and titanium dioxide) in sunscreen

Glogster Gallery Walk

Directions: Watch Austin's Butterfly Video <https://www.youtube.com/watch?v=hqh1MRWZjms>

Today we are going to do a "gallery walk" to look at each other's Glogster Posters and provide feedback to each other. Reflect on why we watched the video about Austin's Butterfly before the gallery walk:

Guidelines for Feedback

- Be helpful, specific and kind!
- Helpful feedback can be
 - "Praise"- Tell *why* you like it or *what* is a strength of the project
 - "Question"- Ask questions about pieces of the project that are unclear
 - "Polish"- Provide suggestions for improvement
- Your feedback can start with
 - I like...
 - I wonder...
 - I suggest...

Gallery Walk Protocol

1. Find a computer and open up your Glogster. Make sure the computer has a full battery and the Glogster is enlarged for easy viewing.
2. Make sure you have sticky notes (provided by your teacher) and a pen or pencil.
3. When we are all ready, we will circulate around the room and write feedback on sticky notes.
4. SILENTLY record feedback on sticky notes and place them by the laptops.
5. If you notice a laptop without many sticky notes, go to that Glogster and try to provide meaningful feedback.
6. After 15 minutes we will end the gallery walk and you may go to your project to collect feedback on your own project.
7. Reflect on the feedback you have received and spend another 15 minutes modifying your project based on the feedback you received.

Reflection

After receiving feedback, what are some modifications or additions you will make to your project?

Easel.ly Charrette

Feedback Reflection

Directions: Think back to the Gallery Walk.

What are some important guidelines for feedback?

What are some sentence starters you can use when providing feedback?

Charrette Protocol

1. **Set Up (5 minutes)**- Find a computer and open up your Easel.ly. Make sure the computer has a full battery and the Easel.ly is enlarged for easy viewing.
2. **Presentation (3 minutes)**- Presenter explains their Easel.ly to their partner. This can explain the process the presenter went through to create it. The partner listens without talking.
3. **Framing Question (1 minute)**- Presenter asks a specific question to guide the feedback. This could clarify where you are confused or what you especially want help with.
4. **Feedback (2 minutes)**- Partner gives suggestions (*be helpful, specific and kind*). Presenter listens.
5. **Open discussion (2 minutes)**- Presenter and partner have a dialogue (back and forth) about the suggestions and feedback.
6. **Reflect on the feedback** you have received and spend another **10 minutes** modifying your project based on the feedback you received.

Reflection:

After receiving feedback, what are some modifications or additions you will make to your project?

Critical Friends Peer-Assessment

Feedback Reflection

Directions: Think back to the Gallery Walk and the Charrette.

What does good feedback sound like?

What does good feedback feel like?

Critical Friends Protocol

1. **Set Up (5 minutes)**- Find a computer and open up your website. Make sure the computer has a full battery and is enlarged for easy viewing. Get out your Video/Animation Rubric.
2. **Group (2 minutes)**- Find a group of 3 people (not 2 and not 4). Preferably these are people who are not familiar with your work already. You want fresh eyes!
3. **Presentation (5 minutes)**- Presenter gives his/her Video/Animation Rubric to the audience and then presents his/her project as if it were the real thing. Audience listens.
4. **Clarification (2 minutes)**- Audience asks short clarifying questions. Presenters respond.
5. **Assessment (1 minute)**- Audience quietly uses the Rubric to assess the project, placing marks in the "Critical Friends Peer Assessment" column. Presenters look the other direction.
6. **"I like..." (2 minutes)**- Audience shares what they liked. Presenters listen without speaking.
7. **"I wonder..." (2 minutes)**- Audience shares concerns (missing features, incorrect information, practical issues like sound and viewing). Presenters listen without speaking.
8. **"I have..." (2 minutes)**- Audience shares ideas, resources or suggestions for the project. Presenters may respond.
9. **Reflection (2 minutes)**- Presenters reflect on useful feedback, audience listens.

Note Taking Guide for Critical Friends Protocol

"I like..." (Strengths of the project. Refer to the rubric if needed)

"I wonder..." (Potential weaknesses of the project. Refer to the rubric if needed)

"I have..." (Ideas you have that might enhance the project, resources, materials or other suggestions)

Tips for Good Notes₁

Sources

- ❖ Write down your source before you start taking notes.
- ❖ If you copy word for word from your source, use “quotation marks” and list your source.
- ❖ On your website, cite your internet sources the way did I here!

Taking Notes

- ❖ Make sure you understand the driving question. This is what you are trying to answer.
- ❖ Start with easy to understand sources, then tackle the “tough stuff.”
- ❖ Scan titles or subtitles to decide which parts of the article are relevant. You might read the whole thing or you might not.
- ❖ Don’t start taking notes immediately- read a whole section for understanding and then start taking notes.
- ❖ Take notes in short phrases “caveman speech” into a graphic organizer.
- ❖ Use abbreviations, symbols, or sketches in your notes.
- ❖ Find important (or key) words and make sure you can define them.
- ❖ Don’t be afraid to use the dictionary (or dictionary.com) if you are confused.
- ❖ Don’t write down what you don’t understand.
- ❖ Reread your source to understand better.
- ❖ Summarize your learning – read, make sense of it, and put it in your own words.

1. http://infotech.spsd.org/MS/ms_research_step4.html

Organizer for Video or Animation

1. What I already know:
 - a. The properties of my element are: *(Hint: Look back at your Glogster!)*
 - b. The structure of my element: *(Hint: How many p, n and e, how many valence electrons? You may want to draw a bohr or lewis dot diagram or look back at your electron configuration.)*
 - c. Why this element is important to us: *(Hint: re-read the notes from your research and SUMMARIZE. Do NOT try to include all the details here.)*
2. Now answer the driving question IN YOUR OWN WORDS: How do the properties and/or structure of your element impact our daily lives? *(Hint: put together your answers to questions a, b and c above)*

Facts from my research that support my answer: *(Hint: look back at the graphic organizer for research)*

Fact _____

Source (from graphic organizer): 1 2 3 4 5 6 7 8

Fact _____

Source (from graphic organizer): 1 2 3 4 5 6 7 8

Fact _____

Source (from graphic organizer): 1 2 3 4 5 6 7 8

Fact _____

Source (from graphic organizer): 1 2 3 4 5 6 7 8

Fact _____

Source (from graphic organizer): 1 2 3 4 5 6 7 8

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Source (from graphic organizer): 1 2 3 4 5 6 7 8

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Fact_____

Source (from graphic organizer): 1 2 3 4 5 6 7 8

Fact_____

Source (from graphic organizer): 1 2 3 4 5 6 7 8

Fact_____

Source (from graphic organizer): 1 2 3 4 5 6 7

Appendix B

Principal Letter of Consent

North Farmington High School
National Exemplary School
32900 W. 13 Mile Road
Farmington Hills, MI 48334-1904
Phone: 248-785-2005 Fax: 248-855-2060

June 23, 2014

Dear Mr. Steven Smith,

The purpose of this letter is to give my approval to Elizabeth Crane to conduct her master's thesis research project, *Project Based Learning in the Chemistry Classroom*, at North Farmington High School during the 2014-2015 school year.

I understand that this research poses no foreseeable risk to the students and that Mrs. Crane will take every possible effort to protect the identity of the students who volunteer to be a part of the study.

If you have questions, you may contact me by email at joseph.green@farmington.k12.mi.us

Sincerely,

Joe Green
North Farmington High School Principal

Appendix C

Parental Consent and Student Assent Form

Dear Students and Parents/Guardians:

Along with teaching Chemistry, I am currently pursuing a master's degree at Michigan State University. This trimester I will be conducting a research project as part of my degree program and I would like to take this opportunity to invite your child to participate. There are no unique activities related to this research and participation in this study will not increase or decrease the amount of work that students do. Researchers are required to provide a consent form like this to inform you about the study, to explain that participation is voluntary and to explain risks and benefits of participation.

What is the purpose of this research? I have been working on effective ways to incorporate project based learning into the chemistry curriculum and I plan to study the results of this teaching strategy on student comprehension. The results of this research will contribute to my understanding of best teaching practices.

What will students do? Students will participate in the usual curriculum for Chemistry, but with added emphasis on project based learning. Students will complete the usual assignments, assessments and pre/post tests, as they would do normally. I will simply make copies of students' work for research purposes. I am asking for permission to use copies of student work for my research.

What are the potential benefits? I anticipate that my research will improve the quality of instruction that your child receives. I will report the results in my master's thesis so that other teachers and students can benefit from my findings.

What are the potential risks? There are no foreseeable risks associated with participating in this research. I will not open consent forms (where you say "yes" or "no") until after I have assigned final grades for the trimester. That way, I will not know who agrees to participate in the research until after grades are issued. In the meantime, I will save all written work. Later, I will analyze the written work only for students who have agreed to participate in the study and whose parents/guardians have consented.

How will privacy and confidentiality be protected? Students' names will not be reported in my master's thesis or in any other dissemination of the results of this research. Instead, the data will consist of class averages and samples of student work that will not include names. The only people who will have access to the data are me, my thesis committee at MSU, and the Institutional Review Board at MSU. The data will be stored on password-protected computers during the study and on password protected computers at MSU for at least three years after the study (in compliance with the law).

What are your rights to participate, say no, or withdraw? Participation in this research is completely voluntary. You have the right to say "no." You may change your mind at any time and withdraw. If either the student or parent/guardian request to withdraw, the student's

information will not be used in this study. There are no penalties for saying “no” or choosing to withdraw.

Who can you contact with questions and concerns? If you have questions or concerns about this study, please do not hesitate to contact:

Mrs. Elizabeth Crane
North Farmington High School
32900 W. 13 Mile Road
Farmington Hills, MI 48336
elizabeth.crane@farmington.k12.mi.us
(248) 426-1191

Dr. Merle Heidemann
118 North Kedzie Lab
Michigan State University
East Lansing, MI 48824
heidma2@msu.edu
(517) 432-2152 ext. 107

If you have questions or concerns regarding your child’s role as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if desired, MSU Human Research Protection Program at: **irb@msu.edu**

How should I submit this consent form? Please complete the attached form. Both the student and parent/guardian must sign the form. Please return with your student a form indicating interest either way. **Please return this form to the dropbox in my classroom, room 401 by Friday October 24th.**

Sincerely,
Elizabeth Crane

Parents/guardians should complete this following consent information:

I voluntarily agree to have _____
participate in this study.

(Please PRINT Student Name)

Please **CHECK ONE** of the lines below:

Data

_____ YES I give Elizabeth Crane permission to use data generated from my child's work in this class for her research project. All data shall remain confidential.	_____ NO I do not wish to have my child's work used in this thesis project. I acknowledge that my child's work will be graded in the same manner regardless of participation in this research.
---	---

Please **CHECK ONE** of the lines below:

Photography, Audiotaping, or Videotaping

_____ YES I give Elizabeth Crane permission to use photos or videotapes of child in the classroom doing work related to this thesis project. I understand that my child will not be identified.	_____ NO I do not wish to have my child's images used at any time during this thesis project.
--	--

(Parent Signature)

(Date)

(Student Signature)

(Date)

Please return this form to the dropbox in my classroom, room 401 by Friday October 24th.

Appendix D

Pre/Post Test

_____ 1. A container holds iron, oxygen, water and wood.

Substance	Density
Iron	7.86 g/mL
Oxygen	0.0014 g/mL
Water	1.0 g/mL
Wood	0.40 g/mL

After shaking the container and waiting for everything to settle based on density, which would be found on the bottom?

- a. iron b. oxygen c. water d. wood

_____ 2. Atomic number is ALWAYS the number of _____ in an atom.

- a. protons b. electrons c. neutrons d. nothing

_____ 3. Valence electrons are located in the _____ of an atom.

- a. nucleus b. K shell c. L shell d. outermost shell

_____ 4. Which of the following is an ion? (CIRCLE ALL THAT APPLY!)

- a. Ca b. Na^{+1} c. N^{-3} d. F

_____ 5. Which of the following is an isotope of Carbon -12? (CIRCLE ALL THAT APPLY!)

- a. Carbon with a mass of 13 amu d. Carbon with 6 protons and 8 neutrons
b. Carbon with 7 protons
c. Nitrogen-12

_____ 6. Which of the following is an ionic compound? (CIRCLE ALL THAT APPLY!)

- a. CO_2 c. H_2
b. NaCl d. Al_2O_3

_____ 7. The total charge on any compound must add up to _____.

8. Draw a Bohr Diagram for beryllium in the space provided. You must write the number of PROTONS and NEUTRONS in the nucleus (the circle).

Item 8: correct number of protons

Item 9: correct number of neutrons

Item 10: correct number of electrons

Items 11: correct placement of electrons in shells

9. Write the complete electron configuration and abbreviated electron configuration for the following bromine in the space provided.

Bromine

Item 12: correct symbol, Item 13: correct complete configuration, Item 14: correct noble gas, Item 15: correct abbreviated configuration

10. Draw the Lewis dot diagrams for the following **atoms and their ions**.

calcium

*Item 16:
correct dot
diagram of
calcium*

iodine

*Item 17:
correct dot
diagram of
iodine*

11. The average atomic mass of hydrogen is 1.01 amu. The three isotopes of hydrogen are:

Hydrogen -1
Hydrogen -2
Hydrogen - 3

*Item 18:
identification of
most abundant
isotope*

Which isotope is the most abundant (common)? _____

Appendix E

Project Reflection Questions

1. Describe what you were supposed to accomplish with this project.
2. What section of the project was most frustrating for you to do and WHY?
3. What section of the project was most enjoyable for you to do and WHY?
4. Summarize what you learned about the element or compound you investigated for your presentation.
5. Describe what skills were needed to accomplish this project and how you improved those skills.
6. What kind of feedback did you receive during the project and how did you change your project based on that feedback?
7. Do you prefer this type of project based learning or more traditional lecture-based learning and WHY?
8. Did having a choice in your project (choosing an element and a presentation style) make the project more enjoyable? WHY or WHY NOT?
9. Did using digital presentations make the project more enjoyable? WHY or WHY NOT?

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