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Science Concepts Visualization and Classroom Engagement Through Technology and Simulations

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Science Concepts Visualization and Classroom Engagement Through Technology and Simulations

By Kaylee Santos

A thesis submitted to

The Department of Education and Human Development of

The State University of New York College at Brockport

in partial fulfillment of the requirements for the degree of

Master of Science in Education
“You cannot hope to build a better world without improving the individuals. To that end, each of us must work for our own improvement.”

-Marie Curie (1867-1934)

This paper is dedicated to the individuals that have pushed me to be my “best self”. I thank my partner Marlon and my children Hailie and Cataléya for keeping me grounded and providing the motivation that has helped me reach many accomplishments.
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Chapter 1: Introduction

Problem Statement

Chemistry is a science that can be difficult for students to understand. This physical science involves a lot of abstract thinking. Therefore, it can be difficult for students to conceptualize concepts learned. Integration of technology in the classroom can prove as a useful tool to enhance classroom learning and encourage students’ engagement. Research indicates that virtual simulations provide a reference for students to use when remembering or discussing concepts (Lee et al., 2009, page 82). Integration of meaningful virtual simulations help students to make connections to what they are learning.

Ground Work for Project Design

Technology has been discussed by multiple studies as a powerful tool in the classroom. Students from this generation are highly entangled with technology. It can be said that students have grown a dependency on technology. A benefit from this dependency is the familiarity students have from being exposed to technology. Technology integration can be flawlessly integrated into any curriculum due to students experience with this type of tool. The relationship students have with technology provides opportunity for positive integration of virtual simulations and activities in the classroom. Students’ receptiveness of integrating technology in the classroom was another common theme identified in research studies. Students appreciate being able to research and “see” relationship being studied (Lui, M., & Slotta, D., 2012, Page 76). Being able to “see” relationships play a big role in chemistry and simulation prove useful in delivering virtual visuals not readily easy in real life. This receptiveness also improves students’ engagement in the classroom.
Technology integration works as a tool to deepen student understanding. Virtual simulation gave opportunity for a visual presentation of phenomenon students learn about in the classroom. The cognitive theory of multimedia explains that our minds process visual information by selecting relevant information, organizing it and then integrating into current knowledge (Lee, H., Plass, J. L., & Homer, B. D., 2006, page 903). These simulations help students understand relationships learned about in chemistry in a much deeper level. Virtual simulations work as a useful tool to improved quality of content understanding in the classroom. Studies have shown that students using simulations in the classroom outperformed students in traditional classrooms (Anderson, J., & Barnett, M., 2013, Page 920). Not only has simulations helped raised test scores, it also encourages scientific discourse in the classroom.
Chapter 2: Literature Review

Contemporary Trends in Science Education

Student Perception of technology use in the classroom

Overall, a student’s understanding will always remain the key directive for all involved with teaching in institution of learning. However, students are voicing their disagreement with the traditional form of teaching. Simultaneously, technology has become synonymous within social interaction and continues to be a major contributing attribute on the forefront of society, especially when it deals with employment opportunities. Applications, programs, devices are not uncommon as they were two decades ago, and children are now more than ever growing up with technology at the earliest stages of life. As referenced in the review “with the onslaught of group chats, group texts and social media platform, today’s students may be more adapt at working within a group than they are individually (Hoffmann & Ramirez, 2018).” Startups and businesses are constantly looking for not just the innovators but individuals who will strive in group settings especially in group projects and activities. Students are interested in using technology, educators only need to help teach students the proper usage of this technology.

Students are interconnected at home and have the expectations of being just as connected to technology in the classroom. The research discusses the relationship students have with technology in schools. Factors that limited the use of technology in the classroom are discussed. Students perception was identified through a school wide survey administered in a high school in southern California, where only 22% of students qualified for free or reduced lunch (Hoffmann & Ramirez, 2018, page 52).

There were some major findings that stood out in this research. First, student perception of technology’s connection to their learning is indicated by survey results. 78% of students
expressed that technology usage during learning encourages participation (Hoffmann, et.al. 2018, page 53). Students’ perception in this study indicates that using technology as an assistive tool can help engage students in large classrooms and hard to reach students.

Another finding is the students’ perception of quality of technology usage. When a student does not understand something, they have the ability to research on their phones at the current moment. Students have grown up using devices and are able to incorporate devices in learning. This notion is supported in the surveys when it is observed that 92% of students feel confident in using technology in their own learning (Hoffmann, et.al. 2018, page 53). Students’ willingness to use technology could provide teacher the opportunity to teach appropriate use which carries on into adulthood.

One aspect this study fails to highlight are issues that arise from the implementation of technology in the classroom. Students tend to use up their data or have poor service in the classroom. Although this could be easily remedied by providing access to Wi-Fi, some schools simply do not have the budget to do so. Availability of resources and support for such issues are not always readily available to assist teachers in the classroom.

Another issue not discussed is the correlation of technology use in schools with student from low income homes. The research was based on students in medium income homes. It is not apparent that there is a lack of availability of technology to the students in this research. Not all schools have 1 to 1 technology availability for students. Therefore, students not having access to cellphones due to financial reason need to use school provided technology.

An implication discussed in this study is the teacher’s perceptions of technology usage in the classroom. A common discussion in articles relating to teachers and technology usage is the lack in comfortability of incorporating it in the classroom. It is discussed that teachers feel
uncomfortable of using technology due to lack of experience in using it (Hoffmann, et.al. 2018, pg. 51). Another reason for discomfort is the possibility of students becoming distracted by using technology for reasons other than the current classroom task. Solutions discussed included the availability of professional development to help teachers learn how to use the technology in the classroom. However, a possible solution for teachers in school districts with low funds where this availability is scarce is not discussed.

Teacher’s Perception of Technology Integration in the Classroom

The choice of integrating technology in the classroom can be a useful tool. It is up to the teacher to choose whether or not include it. Background knowledge and experience of technology integration has a lot of influence in how the teacher chooses to deliver content in the classroom. Rehmat and Bailey address the importance of effectively integrating technology in the classroom. The difficulty teachers have in incorporating technology in the classroom is identified. There are many benefits that can come of integrating technology in lessons, but teachers find it challenging due to lack of experience with such tools. Preservice teachers were asked about their views on technology integration pre and post service in elementary science classrooms. This identified that preservice teachers’ beliefs that hindered the possible integration of technology in the classroom (Rehmat, A., & Bailey, J., 2014, page 745). It was also identified that teachers struggled aligning technology with the curriculum.

Prior to beginning the study, preservice members answered a survey with open ended questions about their personal definition of technology (Rehmat, et.al., page 748). This was intentionally done in order to identify presumption preservice teacher had about
the inclusion of technology in the classroom. An observation that was identified as concerning was the effect of how these preservice teachers learned their science core influences their teaching. In fact, most learned traditionally with the use of books and lectures (Rehmat, et.al., page 748). This is why Rehmat and Bailey led to the conclusion that the manner the content was learned causes that distance teachers have with incorporating technology in their classrooms.

The proposed solution by Rehmat and Bailey was to address this issue with preservice teachers before they go on the field. This proposed solution incorporated a framework called TPACK. The TPACK model is a Venn diagram that demonstrates the relationship between curriculum, technological and pedological knowledge (Rehmat, et.al., page 745). This tool was used in order to help create that connection between science learning and technology for the preservice teachers. Before entering the classroom, preservice teachers were assisted in creating lesson plans that would effectively integrate technology in the topics learned. The effectiveness was measured by having preservice teachers’ complete surveys at the end of each lesson in order to gauge how comfortable they felt about the use of technology in the classroom. This solution assured that preservice teachers enter the field with the knowledge needed in order comfortably integrate technology in lessons.

It is certain that after learning to effectively use technology, teachers can see the multitude of possibilities for content delivery. After creating and using lessons in the classroom, preservice members discussed their new observations toward the usage of technology in the classroom. Some preservice teachers identified that when technology is integrated correctly, students can greatly benefit from using technology in the classroom.
Rehmat and Bailey discuss the support of virtual data collection that is not possible in real life in the classroom (Rehmat, et.al., page 747). This skill was observed to help students connect what they are learning to the real world. Another benefit discussed is the ability of providing student the opportunity to see first-hand phenomenon that are hard to observe in real life (Rehmat, et.al., page 753). This helps students make connections in curriculum and visuals. This also helps cater the need of visual learners by providing the ability to manipulate elements through the use of simulations (Rehmat, et.al., page 753).

A weakness in the study was the sample size used for data collection. The groups involved in the study were preservice teachers enrolled in a class at a university. This ran the risk of observation and data collected to lack preciseness. Although, an inference made about the teacher population at a large scale could have its inaccuracies, conclusion about the effectiveness of technology used in the classroom is no necessarily inaccurate. The study fails to consider that a wider pool of teacher in such surveys can demonstrate that teachers already in the field show comfortability with the use of technology in the classroom.

From participation in this research, the preservice teachers left with a much better outlook on technology. Many expressed the excitement of using technology in future lesson and were already preplanning activities (Rehmat, et.al., page 753). The study did not focus on the student’s perspective but from various studies discussed in the research, it demonstrates the importance of student center activities. It was identified many studies that discuss the increase in lesson effectiveness for students (Rehmat, et.al., page 754).
The studies discussed also indicate the relationship students have with technology and the willingness of students to want to learn from them.

*Micro-lectures and Flexibility of Learning/Teaching Through Micro-lectures*

Further development of technological tools are finding ways of improving quality of teaching in the classroom. Teachers already in the field find it hard to incorporate these tools to in-classroom learning. Micro lectures, an example like Khan’s academy, have picked up success for out-of-school and tutoring curriculum assistance. Micro lectures are an effective way that can be incorporated as self-reflecting tool by educators (Lü, L., 2018, pg. 39). Lack of technological knowledge relating to micro-lectures are identified as possible reasons why teacher misconstrued the usefulness in the classroom. Misconception that can arise is the belief that micro lecture *does* the teaching rather than facilitate it (Lü, L., 2018, pg. 40). Indeed, implementation of technology in the classroom is imminent, teachers will not be completely replaced with a motion detecting screen with learning objectives on standby. Teachers will be permanently entrenched as educators because of the guidance they provide.

The concept of creating micro lectures was explored through a process of self-learning. The research was designated to facilitate the willingness of using technology in teaching practices. This could be gained by concluding with a much more positive view on technology integration in the classroom. Lack of experience cause teachers to become less confident in integrating technology for educating students. Lü suggest exploring technology by research and application. Lü discusses the experience of reflecting on teaching from self-made micro lectures. Teachers have the power of choosing what to teach, when to teach and how to teach it. When creating micro -lectures, the educator has the control of the content shown and how is being
delivered. Using technology to create supplement for instruction helps facilitate innovative ways to create visual that teachers can use in lesson.

The research suggests teachers creating micro lectures as both a way to facilitate teaching and a way to self-critique teaching practices. Although the promise behind this tool, teachers refrain from using it due to lack of expertise (Lü, L., 2018, pg. 40). Tools like TPACK, a teaching model that relates technology with pedagogy, have been created to facilitate an effective way of incorporating technology in curriculum. TPACK helps teachers gain confidence in using technology in teaching practices. Using TPACK, teachers can successfully integrate their knowledges on content with technology using micro lectures (Lü, L., 2018, pg. 41).

Realizations from this research that are of importance include the concept of time and location in teaching. Lü discusses the discovery of micro lessons facilitates for teaching to happen anywhere and at any time. Micro lesson rids of any restrictions of when learning occurs. This became a benefit that could promote educators to use technology more often. It was discussed that teacher choose the ability of what content is being delivered and how it’s being delivered (46). This readily remedies the misconception of micro lecture doing the teaching.

Another conclusion was the thought process needed when making the videos. Using frameworks of critical viewing, Lü discovered ways to assure the micro video effectively delivered instruction to the intended students. Lü wanted to make sure that the micro video promoted “active cognitive learning” (Lü, L., 2018, pg. 44). This observation helps guide teacher assure that the purpose of the video is met and that it facilitates learning the way it was intended.

A weakness in the study is the failure to discuss how the effectiveness of the created micro lecture was gauged in the classroom. Various point in the study Lü discusses the experience of self-improvement when creating the micro lectures. It lacked a discussion if the
final product (micro-lecture) created was indeed effective in the teachers’ personal classroom. Findings of personal growth and developed mindset after creating the micro-lecture is discussed. But the previous training/knowledge that might have helped in the use of technology was not evident.

Overall, the integration of micro lectures in the teaching served multiple purposes. In one hand, an educator can learn technological skills and knowledge that was not known before through self-efficacy (Lü, L., 2018, pg. 45). In the other hand, an educator adds another supplement to the content they are teaching in the classroom. The major goal is to help engage students in different ways and increasing content efficiency. Using innovative ways of technology integration helps both the students and teachers learn with more efficiency.

Cooperative Learning Using Technology in a Science Classroom

Classroom lessons are structured to contain a learning goal. Cooperation means as a group, students work together to make that goal. Altun discusses the importance and effectiveness of including cooperative learning in the classroom. This study included a pre and posttest to gauges understanding and effectivity of cooperative learning in the classroom. Even though cooperative learning can cause unnecessary pressure on students not willing to collaborate, it enhances learning through lesson differentiation and provides support for learning as presented in this study.

A classroom of 20 students was used for this study (Altun, S., 2015, page 451). The ratio of girls to boys was approximately 1:2. Quantitative data (T-test results) and qualitative data (interview of students) was used to measure the effectiveness of cooperative learning in this particular classroom. The results reflected a positive impact
of this strategy in this particular classroom. The mean values for the exams when from
52.4 pretest to 76.2 post-test. This showed a great increase in the mean test for students.

A major finding that supports the need of incorporating cooperative learning
would be the increase in scientific discourse (Altun, S., 2015, page 453). When using
cooperative learning in a lesson, discussion is part of this strategy in the classroom.
From each other, students can learn to use scientific words and further develop
scientific language by learning how to use vocabulary from other students. This skill
practice is imperative for students to learn for success in future science classrooms.
Students may learn new vocabulary but do not know how to use them in terms of
discussion. Facilitating student collaboration and discussion can help student model to
each how to correctly use words in context.

Another major finding identified in the study was that this strategy develops
critical thinking skills, problem solving skills and learning to cooperate with others.
These skills are important for the students’ future. By supporting their peers’ learning,
long term learning of concepts is supported (Altun, S., 2015, page 453). This means
that a student fosters learning by teaching/reteaching concepts learned in class to
another peer.

One aspect that was not properly studied was the negative side of cooperative
learning. The study identifies the need of student success as a negative pressure placed
on non-participating students (Altun, S., 2015, page 462). However, a discussion of
how high performing students is not found. Altun discusses how low skills in
communication was a possible reason for low performing students. A discussion of
possible issues of work integrity and methods of how students work load was regulated
(equal contribution of work). Another factor not considered is the possible lack of rigor for high performing students. This particular group of students can easily become disengaged if they are found to continuously explain concepts to other students.

Implications not discussed would include how cooperative learning would work in large classroom size. The classroom used for this study included a class size of 20. Problems that could arise in large classroom when using the cooperative learning strategy include students remaining on task and regulating participation (some students might “hog” discussions).

Another implication is the efficiency of cooperative learning in different situations. In other words, the quality of discussions in classrooms with ELL students or students with mixed cognitive abilities. Altun discusses the use of cooperative learning as an opportunity for lower level learning students to learn from higher level learning students. This may have worked for this particular study, but a question is how functional this strategy would be in classrooms of a different scenario.

A third implication that could have been discussed was the effectiveness of cooperative learning for different genders. Often times it has been observed that girls lack confidence in STEM subjects. The classroom in this study included double the number of male students vs. female students. A comparison in these results would have improved quality of data reported.

A final implication to consider is that the population of students discussed in this study are based in another region. The classroom used was based in Istanbul. The result that indicated effectiveness may vary due to geographical location. Meaning, the curriculum and rigor in Istanbul might vary to that of a classroom in a different region.
Flipped Lessons and Technology

Flipped lessons are an instructional strategy used in the classroom. Flipped lessons help educators to change how lessons are delivered in order to use class time to review topics and correct misconceptions. Jeong, Gonzalez-Gomez and Cañada-Cañada study the students’ view of a flipped classroom. It is found more than often that we consider the statistical aspect of how effective instructional strategies are in the classroom. This study goes further by also discussing the emotional acceptance of this strategy being used outside the classroom.

This study was done in a science classroom at a university in Spain. The purpose of this study was to gauge the mental representation of students while using this type of strategy in the classroom. The overall classroom size consisted of 65 students. The female to male ratio of students in this classroom was 1:2.

The overall study included a variety of content presented to students a week prior to starting a new topic. In order to gauge effectiveness of understanding, students completed a quiz at the end of each flipped topic in order to gauge the effectiveness of the content (Jeong, J., González-Gómez, D., & Cañada-Cañada, F., 2016, page 750). The professor provided feedback during these quizzes to help prepare students for the topic the following week. As identified in the study, flipped lessons provided opportunity for majority of the classroom time to be spent on the application of the topic (Jeong, J., González-Gómez, D., & Cañada-Cañada, F., 2016, page 750). In other words, classroom time was maximized and provided the educator time to address any misconceptions identified. This also meant that students did long term learning by applying what was learned in the classroom. The students perception of flipped classroom learning was identified by having students fill out surveys during classroom time.
An effective finding in the study was the use of familiar display of content. Flipped lessons were shown similarly to how lessons were presented in class. 80 percent of students felt comfortable with this type of delivery in flipped lesson due to familiarity (Jeong, J., González-Gómez, D., & Cañada-Cañada, F., 2016, page 752). The students demonstrated the importance/need of a comfortable learning environment both in and out of the classroom.

Another effective finding was the student’s approval of how content knowledge was gauged. Students enjoyed instant feedback from end of lesson quizzes. 72% of students found that the quizzes gave feedback to valuably gauge how well content was understood (Jeong, J., González-Gómez, D., & Cañada-Cañada, F., 2016, page 753). Students were able to use this type of feedback to make check content knowledge and use this as an indicator of what content needed to be reviewed.

A strength in this study was the factors considered. The students’ gender and educational background considered when evaluating data collected. It was found that regardless of the students’ background, flipped lessons were successful and widely accepted by selected student population (Jeong, J., González-Gómez, D., & Cañada-Cañada, F., 2016, page 755).

A weakness identified in this study would include student’s economical background and its influence on students’ success with flipped lessons. The article does not identify students economic background, nor does it identify the accessibility of technology at home. These factors are a consideration needed in this study because a lot of the flipped lesson took place online at home. Alternate way of delivering instructions could have been discussed for these situations. It would have also been helpful to see how the lack of technology could have influence/changed outcomes of results for this study.
Another weakness identified in this study would be the age group used in the study. The students used in this study were first- and second-year college students. A discussion how these results would have differed with a much younger set of students could not be found. Using certain strategies in the manner they are used could vary the acceptably due to knowledge of prior usage. In other words, colleges students have the motivation for self-efficacy which makes this strategy effective, while younger students might still be developing the self-efficacy skill that would benefit the success of this strategy. This strategy is mean to supplement student learning, younger students might view this as homework and might be reluctant to complete assignments before classroom instruction.

Implications discussed included students’ emotional acceptance of flipped lesson. When considering different modes of instruction, it is easy to inclusively think about the effectiveness of quality of learning. The study demonstrated the confidence student had in hard to learn topics when given the opportunity to pre-learn in the comfortability of their own home at their own pace.

An implication that was not discussed in this study would be the perception of an educators view on flipped lessons. An educator might find it easier to gauge student understanding of a topic by focusing on student centered activities after students have learned about the topic at home. Educators can also extend pacing for classroom that lead to high stake end of year exams.

Differentiation Instruction

Differentiation is an important component of instructions. It is important to understand that each student has a unique learning style and that not all students learn alike. The study
demonstrates the importance and effectiveness of tailoring the content to the meet the students’
was discussed that the success of this strategy was compared to the academic effectiveness due
to ability groups, teaching competency and differentiation knowledge of educators. Teacher
increasing knowledge on the application of this strategy can increase student achievement by
teachers to comfortably use it in their classroom, effectively apply this strategy to increases
student achievements, and increase knowledge in this strategy in order to successfully apply this
in the classroom.

As part of this study, teachers from a selected school district were selected to participate
in this study. Professional development was used to measure teachers’ competency in the
subjects and teaching strategies. It was also used to help educate teachers of ways to differentiate
instruction. Teacher applied what was learned into their own classrooms. Effectiveness of
application in the classroom was gauged by teacher survey responses in the cohorts and student
achievement during multiple time in the year. In order to support teachers in this process, staff
were designated as coaches for the teachers. These coaches led meetings and provided
constructive feedback to help teachers further develop their lesson plans (Prast et al., 2018, page
26).

An evident argument presented in this study is the importance of teacher competency in
differentiating instruction for a given topic. The increase in student understanding was shown a
gradual increase after the first few cohorts. The data analysis demonstrates that students in lower
levels gained knowledge in the subject a lot faster than before (page 22). An increase in students’
grades on the CMT of 2.5 points also demonstrated the effectiveness of this application (Prast et
al., 2018, page 22). Teacher competency of differentiation of instruction helped increase student
scores in the classroom. The teachers view on how affective differentiation was in the classroom was gathered through surveys. Teachers reported positive on student motivation and achievement in their classroom (Prast et al., 2018, page 28). Teachers also reported that they learned how and properly applied lesson adaption to whole classroom and different ability groups (Prast et al., 2018, page 28). Attending professional development for this strategy helped teachers to be more comfortable with integrating this strategy in their own classroom. Although a drastic increase of students’ success in academia was not observed (mostly due to small sample size), teacher that attended walk away with a career long skill that can be used in the classroom. Teachers demonstrated the ability to modify lessons to differentiate content ability effectively and comfortably (Prast et al., 2018, page 28).

A weakness presented in this study was the inconsistency of quality data collection from year 1 vs. year 2 of the study. In fact, the data revealed that the amount of achievement in average achieving students demonstrated higher improvement than the grades of low achieving students (Prast et al., 2018, page 30). The weakness for the data was discussed be the small sample size used. If effectiveness were solely based on quantitative data, the results would be poor. Qualitative received from teacher feedback demonstrated that differentiation strategy used in the classroom indeed increased classroom engagements and understanding of rigorous concepts (Prast et al., 2018, page 30).

Implications identified in this study is the guarantee of this strategy improving student learning in the classroom. Prast, Weijer-Bergsma and Kroesbergen discuss that the effectiveness of this strategy depends on an educator’s ability to apply skills learned about differentiation. Therefore, differentiation will show improvement of classroom learning if strategy is applied correctly. Professional development was used to educate teacher on applying differentiation in
the classroom. Discussed are possible data errors due to inaccurate gauge of how well an educator applied strategy in the classroom.

An implication not discussed in the study are possible effects of other cognitive abilities in the math being gauged. For example, a student whom has strong non-verbal mathematical skill could possibly struggle with word problems due to lack of comprehension in vocabulary. Meaning that students whom English is a second language or has poor reading skills could possibly negatively affect data.

*Computational thinking assists in understanding real-world phenomenon*

Scientific practices help students to learn skills essential in the science field. Neilson & Campbell address the use of mathematics in a physics unit about force and friction (2018, page 26). In this study, the possibilities of applying mathematics across many of the science branches was identified. By integrating math in the unit, students successfully applied computational skills and mathematical skill to analyze friction and force (Neilson & Campbell, 2018, Page 26). The purpose of this integrations was to help students visually see concepts learned. Another purpose identified was using the creation of simulations as a way to help students practice science skills.

Before introducing this activity, students studied Newtons’ first and second law of motion. The activity enhanced students’ understanding by using mathematics and scientific skills help make sense of phenomena. Students used sample models to observe relationship between variables. They were able to make a connection between velocity and force but struggled rationalizing why these variables differed between the smooth block and the sandpaper block (Neilson & Campbell, 2018, Page 28). Using a template, students constructed a model to help investigate why friction was different for the two situations. The models created helped students
understand that friction was affected by normal force and not surface area (Neilson & Campbell, 2018, Page 28).

One major finding was that students were able to use math as a method to “see” and make sense of a phenomena (Neilson & Campbell, 2018, Page 29). The study discusses that the integration of math provided opportunity for more precise simulation of concepts. The exploration of the laws of motion were investigated through the application of various science skills. Students made models to study the different variable involved with friction. Using a force sensor, students were able to record the frictional force and use it to make a quantitative observation. From their data and graph, student created an equation to calculate frictional force using the slope equation from prior math knowledge. Students tested their formula for friction needed by a new heavier block by formulating a theoretical force it needs to move at a constant speed. The results demonstrated to students how accurate their results were. It also demonstrated that the phenomenon was testable and provable. Student successfully created a simulation that gave opportunity for the collection of numerical data that proved these two laws. The formula created from experimental data helped students calculate the frictional force needed for any given mass to move across at constant velocity (Neilson & Campbell, 2018, Page 30).

Additional to creating models, students also practiced fundamental science skills such as observing, measuring and using numbers, engineering and making inferences. Students engineered a device that gave the opportunity for the collection of numeral data (Neilson & Campbell, 2018, Page 28). Students were given an initial model to investigate friction and force. From their observations, students practiced engineering skill by developing a new model that would assist in measuring force and friction. Student displayed data collection competency by
creating and analyzing a graph using the data collected. Finally, students formulated explanations using their data to support it. The application of these skills assured students practiced necessary skill needed in most sciences.

A final finding included the method of assessment in this activity. Different Next Generation Science Standards were assessed through the activity. Science and engineering practices were assessed along with crosscutting concept and disciplinary core ideas. Integration of crosscutting disciplines helped students use prior knowledge to create an understanding and make connections in the physics classroom (Neilson & Campbell, 2018, Page 30).

One implication and weakness not discussed in this study are any difficulty students may have with mathematical skills. The study does not discuss how much prior knowledge students already had with the concepts needed for the activity. The study fails to communicate any possible solutions for students whom may have struggled understanding the application of the slope formula to formulate a force equation.

A weakness in the study was the failure to provide educational background of the students involved in this study. It is relevant for this study because it helps create a setting of student abilities in this classroom. It would have been helpful to identify possible modifications that could accommodate students for this activity.

*Inquiry lessons using technology*

Lee, Linn, Varma & Liu further discuss the integration of technology as an enhancement for science inquiry (2009). In this study, five consecutive lessons involving mitosis were used to implement this tool. Teacher from an entire district were used for this study.
Cohorts were provided as support in the integration of technology for the inquiry unit. Scientific thinking was fostered by scaffolding the delivery of content (Lee et al., 2009, page 79). The purpose of the study was to identify how impact of integrating inquiry lessons in the science classroom. Another purpose of this study was to study the impact of teaching context and knowledge integration (Lee et al., 2009, page 72).

The scaffolding of content helped with long-term learning in students (Lee et al., 2009, page 72 and 74). In the first activity, students brainstorm about implication of the division of cells. During this activity students brainstormed about cancer cells and hypothesized the frequency of cancer cell division. Student are then given 376 images of mitosis and students had to divide the images into the 5 part of mitosis. Using an online forum, students discuss and defend their choices. Students then investigate the possible use of plants for treating cancer. Students conclude this activity by reflection on different cancer research discussed in class.

During the study, multiple methods of assessments were used. Effectiveness was measured by the quality of ideas generated by students through the different activities. A summative assessment included both multiple choice and constructive response questions (Lee et al., 2009, page 76). The data from the formative assessment were compared between classrooms to gauge the receptiveness of the inquiry unit. Data demonstrated that students developed more significant integrated understanding of science topics in the inquiry units versus students in learning from the typical units.

One major finding was provided from the surveys given to the teachers that participated in the study. Teacher shared that simulations provided a reference for students to use when remembering or discussing concepts (Lee et al., 2009, page 82). These references signified the action of long-term learning. Simulations gave students something to always refer to when
discussing mitosis and miosis. Students used these simulations to help explain the phenomena of cell division. Using pictures of different parts of cell division also helped students visually simulate cell division and encouraged students to demonstrate understanding by classification (Lee et al., 2009, page 75). This visualization actually led to the possibility of studying the effectiveness of visuals in inquiry units.

Another finding was the effectiveness of using real-world application to relate with the content students are learning about. Students applied knowledge of mitosis to explain how cancer happens in the body. The study uses cancer as a meaningful content for this particular subject (Lee et al., 2009, page 75). Students investigated possible usage of different plants to treat cancer with the use of a simulation program (Lee et al., 2009, page 75). This software helped simulation a real-world connection for students to use as a way to deepen understanding and enable long term-learning. The simulation helped students explore a concept that would only be capable of exploring outside the classroom.

A possible weakness identified in this study was from the data collected. Although not explicitly stated in the study, the data table of knowledge integration was comparing data from classroom that used this inquiry-based unit to classrooms whom did not (Lee et al., 2009, page 82). This is considered to be a weakness because application of beneficial techniques should be fairly made available to all students and not just some students. The table almost made it seem as if there was a “control” group. If this is not the case, study fails to indicate whether the data from the tradition units were from past classrooms.

An implication not immediately discussed was the methods used within the inquiry lesson to promote inquiry for students. A major component in inquiry lessons include asking
questions to promote high order thinking. The study implies the use of driving questions, but it does not discuss their impact in student learning for this group (Lee et al., 2009, page 74).

An implication discussed was the need for research to explore data results. When comparing results of the integration of inquiry lesson in different science courses, the result varied in effectiveness (Lee et al., 2009, page 82). It is an interest so see what could have caused the varying results across the sciences.

Learning/Practicing Scientific Skills Using Technology

Real world application of content learned in the classroom serves as an ideal way to integrate skills beneficial for students in the future. Students don’t realize the life skills learned in courses taken in school. For example, students should understand that instead of using “chemistry” in daily life, they are using knowledge from chemistry to know not to combine bleach and ammonium when cleaning a bathroom. Baynard applies real world applications in a chemistry activity that provides students the opportunity to learn problem solving, content knowledge and scientific literacy skills that carry into adulthood.

Baynard incorporated an activity that helped students to integrate technology by reporting, assessing and evaluating different poisons. This inquiry-based project had students choose a poison to research. Baynard taught students in this study how to evaluate the quality of the websites used for data retrieval (2010, page 33). After learning proper research techniques, students researched information about their chosen poison. Students applied what they learned to create a blog post about the assigned poison as a final project. Using technology, students peer evaluated the final product and participated in discussion evaluating poisons’ dangers (Baynard, L., 2010, page 32).
One major finding in this study was the promotion of deeper thinking. The creation of this blog encouraged students to evaluate the poisons by applying different content learned in the semester. The activity assessed various different content concepts at one time that students learned from different units (Baynard, L., 2010, page 32). Content evaluated for this project included chemical formula, physical properties and acidity. Before administering this activity, students learned majority of the content needed in order to understand what they are doing. Students underwent high ordered thinking by evaluating work and becoming experts about their poisons rather than just memorizing facts (Baynard, L., 2010, page 36).

Another major finding was application of scientific discourse through student engagement. Students synthesize research in their blog (Baynard, 2010, page 33). Students practiced scientific discourse when reporting and peer reviewing each other’s work. The online discussions engaged students in the activity. This provided opportunity for the assessment of students understanding by the verbiage used in the discussions.

The teacher helped student deepen their understanding and demonstrate their comprehension with authentic assessment and real-life application. Technology was used as a tool for inquiry-based learning, but it was also demonstrated as way to assess student understanding. This activity gave opportunity for students to apply research methods, policy application and identification of safety issues in substances (Baynard, L., 2010, page 35). The usage of real-world concepts helped students make a connection to chemistry. This connection also led to long-term learning and deepening of understanding (Baynard, L., 2010, page 35-36).

A weakness in the study is the failure to consider different writing skills in the classroom. Students having weak writing skills can hinder what they are trying to say in their blogs. Having
weak writing skills could interfere with the delivery of the knowledge being assessed for this activity. A remedy would have been to include an overall discussion of the different writing abilities in the classroom. This could have followed with possible activity accommodations used to assist students in the writing process of this blog.

Implications not discussed are the limitation of technology students may have at home. In the study, it is discussed that due to time constrains, students were encouraged to complete assignment at home (Baynard, L., 2010, page 32). A discussion of possible modifications for students without home access to computer or the usage of mobile friendly blog was not found.

**Questioning as a Tool for Assessment**

Assessments are a key tool in identifying student knowledge. Aligning assessments to content helps identify what concepts are being properly learned. This also helps identify common misconceptions that can be addressed in the classroom. Assessments help monitor progress by helping instruction, evaluate academics and identifying strength and weaknesses.

This study focuses on using the questioning tool as a method of assessing student knowledge in the classroom. Another focus included the analysis of the quality of short answer responses in classroom assessment. This research takes place in a 1st year students in a science and engineer school in Portugal. The sample size includes 150 undergraduate students with about a 1 to 1 ratio between male and female students.

One major finding in this study was that traditional lecture-based learning was enhanced by incorporating different questioning strategies. Using questions as an assessment tool encouraged classroom discussion and deeper understanding of chemistry knowledge. Before this
integration, students identified in surveys that they did not know what or how to ask a question in order to help guide discussions and understanding (Almeida, P., & Teixeira-Dias, J. J., 2012, page 153). Questions skills were taught through various activities. A few implementations to classroom activities were identified to encourage students questioning and practice.

Scaffolding of activities promoted students to ask more questions in the classroom. Students explored question skill when the teacher incorporated small pauses and the modeling of written questions during lecture (Almeida et, 2012, page 147). Taking small pauses gave opportunity for students to discuss topics with colleagues. This practice allotted time for students to formulate questions they may have about the content and ask out loud at the end of the break. The teacher modeled questioning with several degrees of difficulty (Almeida et, 2012, 147). In this study, the teacher demonstrated using how and why in order to increase deeper discussion in questions about water molecules. This demonstrated how to ask questions with different levels of cognitive difficulty. Activities used to assess students’ quality of question development was done during presentations and a written test. During project presentations, students were assessed by the questions they asked to the presenting groups. As part of this study students were asked to answer a test before and after the integration of this teaching method. Students demonstrated lack of confidence in creating questions. The post survey demonstrated an improvement in the quality of questions in the written response exam. Students identified that developing questions about content learned helped retain information learned and deepen understanding (Almeida et, 2012, 153).

Another interesting find was the integration of technology for this study. The teacher used an online forum to encourage and facilitate student questioning (Almeida et, 2012, 148). Students’ participation was assessed by the quality of participation. In the forum, the teacher
presented phenomena for students to use in discussions. This type of activity encouraged students’ engagement and questioning between students and the teacher. Students modeled to each other how to ask higher ordered questions.

A weakness identified in this study was the small increase in cognitive level integrated in questioning skills. A future implementation to improve this study would be to identify if the low cognitive questions are due to low understanding of concept or lack of questioning skills. Making a connection with content knowledge and questioning skill can demonstrate a significant finding in the study.

An implication not discussed in this study are the teacher’s questioning skills. The study discusses different methods the teacher assessed and modeled questioning in the activities. A discussion about the quality or the measure of the quality of questions asked could not be found. Possibly integrating cohorts that assist teachers in using questions as a method of assessment could be a possible remedy.

*Virtual labs for understanding scientific concepts*

A common theme in studies about the integration of technology in the classroom is the use of simulations to explain phenomena that could not be easily seen in the classroom. This research presents the use of an augmented virtual lab called frame. The study claimed that using science simulations and virtual labs improve understanding of gas behavior because these tools significantly improve test performance and deepens understanding in the relationships of variables involved.

For this study, teachers instructed students through an inquiry-based lab activity followed by teacher-led instruction. The instruction was delivered by using frame. Frame creates a virtual
simulation that combines with physical objects in order to simulate different scenarios. Frame offers physical interaction with objects simultaneously with the virtual program while manipulating variables in the software (Chao, J., Chiu, J. L., Dejaegher, C. J., & Pan, E. A., 2015, page 19). Misconceptions were identified during class discussion and addressed during the lab. An example of one common misconception discovered was already built from prior knowledge of molecular behavior of matter (Chao et al., 2015, page 19). Students suggested that when the temperature of a gas in an enclosed jar cools down, gas molecules will get closer.

The research design used for this study was the quasi-experimental design. This design was used in-order for the researcher to observe students’ natural interaction with the virtual simulations. For this study, the control group were the students studying gases using traditional methods. At during the research, students’ understanding of the relationships of variables was measured and compared to the study group. A few key findings demonstrated the usefulness for this integration.

An interest finding in this study was the improvement of students’ test response (Chao et al., 2015, page 19). This was indicated by significant overall test performance in the group that used the Frame simulation versus the group using the traditional simulations (Chao et al., 2015, page 23). Students demonstrated content understanding by correctly answering specific questions addressing these questions. Students in the research group outperformed the other students in questions relating to the relationship between the number of molecules and volume and the relationship between temperature and pressure. All claims demonstrated strong evidence with p-values less than .05 in the assessments of different ideas for students using Frame as part of the curriculum.
Another interesting finding was the deeper understanding the simulations provided to students. Simulations providing both technological and physical interaction helped students to simultaneously make connections. Long term learning of these concepts was supported with guided inquiry and direct instruction using the simulations (Chao et al., 2015, page 29).

The simulations helped students to create in-depth connections students made of the variables involved with gas properties. Students demonstrated an increase understanding in the interrelationship of the variables involved in the gas laws. Students demonstrated that they understood the connections between the different variable in the gas laws in the macroscopic level.

A weakness identified in this study was the number of students used for this study. Having a larger sample size would help strongly justify the significant benefits of using this tool in the classroom.

An implication discussed in this study was the challenges students face in developing connections between macroscopic and microscopic levels (Chao et al., 2015, page 29). Although the use of the simulation increase understanding about the relationships between the gas law variables, students only described the relationships macroscopically. Students in both the traditional learning and the Frame work learning demonstrated no change in their understanding of the connection between molecular frequency and pressure.

**Hands on activities in the classroom**

Chemistry has many concepts that require innovative ways outside of traditional teaching methods to help student understand concepts. An issue identified that leads to the interest of this
study is the complexity of making chemistry content applicable, accessible and relevant to students (Neff, G. A., Retsek, J., Berber-Jimenez, L., Barber, N., Coles, M., Fintikakis, C., & Huigens, B., 2010, page 48). This study integrates the use of materials in order to understand and address common chemistry misconceptions in the classroom.

For this study, teacher participated in a cohort that taught various methods of incorporating hands-on activities for chemistry subjects. These professional developments assisted middle school and high school teachers. During the workshops, teachers learned methods of enhancing chemistry concept with the use of “material science” (Neff et al., 2010, page 48). As part of the workshop, the topic of bonding was integrated in activities that use everyday materials in order to give students a way to visualize chemistry concepts. This also was done in order to make concepts more applicable. Majority of the content used for this course was not new to teachers. Instead, it was presented in a more innovative manner with every day applications that could help encourage deeper learning in the classroom (Neff et al., 2010, page 49). Easy attainable items like wires, plastic and bags as an example were used in activities to demonstrate bonding.

A major finding in this study was the receptiveness of teachers integrating activities learned in the classroom. Teachers that participated in this study varied in content knowledge levels (Neff et al., 2010, page 50). At the beginning of the PD, teachers were provided with packets that included the needed knowledge for the workshops. This was done to assist teachers that teach chemistry in lower academia levels like elementary and middle school (Neff et al., 2010, page 50). Teachers enjoyed learning how to use daily materials in the classroom. Teacher receptiveness was measured by daily evaluations. These evaluations gave teachers the opportunity to express likes and dislikes about each activity learned (Neff et al., 2010, page 52).
Quantitative data collected from these surveys were used to improve future workshops and the modification of the activities. Teachers also applied activities learned and reported back about the effectiveness of these activities.

Another finding in this study were the different activities used to apply inquiry-based learning in chemistry. Many concepts were explored through inquiry activities that helped students to visualize different properties involved in bonding. Concepts such as melting point, malleability, conductivity and density were applied in the activities taught (Neff et al., 2010, page 51). Polymers were also studied in the workshop. An example discussed using polymers along with other materials to create qualitative study of differing properties (Neff et al., 2010, page 52). Another interesting activity discussed in the study was an activity that helped students observed and comparison of the “stretchy” properties of different materials. The variety of activities used in the workshop demonstrated increased engagement in the teachers (Neff et al., 2010, page 52). It was also reported that teachers noticed increased interest of students in the classroom.

A weakness in the study was the evidence of how effective the application of the learned activities were in the classroom. Teachers identified the effectiveness of these activities but quantitative data demonstrating just “how” effective they were was not identified. Teachers could supplement this research by reporting in-depth data of the effectiveness in the classroom could help modify activities for future workshops.

Implications not discussed in the classroom are the direct impact of these activities on students’ grades and engagement. Teachers participating in the activities demonstrated teacher approval of integrating them in their classroom. Having students’ perceptions of these activities will add more value to the application of everyday items in the classroom.
Classroom Discourse, Questioning and Engagement

One of the integral components of inquiry-based learning include quality of open-ended questions teachers use during the lesson. Teachers use questioning tactics to guide classroom learning and encourage engagements. Effective questions also help with science discourse in the classroom.

In this study, 10 teachers from 2 middle schools participated in this study. To support the teachers in this study, PD sessions were held in order to assist in improving questioning tactics. All 10 teachers were females. The demographics of the students in the study included 1 :1 ratio of male to female population. Race of student that participated in the study were 35% -45% white, 33%- 51% black and the rest were other ethnicities. Approximately less than 54% of students received free and reduced meals. For data collection purposes, a collective amount of formal observations was done by the research team.

The evaluative model used in this study was the EQUIP discourse scale. This scale measured different components that attribute to effective classroom discourse. Components that composed the assessed part of this scale included questioning level, complexity of questions, questioning ecology, communication patterns and classroom interaction (Smart, J, & Marshall, J., 2013, page 254).

An interesting finding in the classroom discovered relationship between classroom discourse and student cognitive levels (Smart, J, & Marshall, J., 2013, page 263). This included using high ordered questions to probe engagements and meaning full discussion. Using effective questioning techniques have been found to develop deeper conceptual understanding of scientific concepts (Smart, J, & Marshall, J., 2013, page 265). Therefore, deeper and long-term learning
was encouraged. The strength of the relationship between effective classroom discourse and cognitive level engagement is prove by the quantitative data collected. A significant value (P<.001) demonstrates the strong influence between the two variables (Smart, J, & Marshall, J., 2013, page 265).

Results from the quantitative data led to further research and identification of another interest finding. Observation and field notes revealed patterns revealed by the analysis of teacher questions during the lessons. This data unveiled that teachers that used higher level questions scored higher in the EQUIP rubric (Proficient (3) and Exemplary (4) scores) that teacher whom did not (Smart, J, & Marshall, J., 2013, page 258). These scores reflected that students constructed deeper explanations and analysis of content learned. An example was observed in this study when students participated in a technological design lesson. This lesson required students to construct a package that would deliver a rare egg across the united states (Smart, J, & Marshall, J., 2013, page 258). During this inquiry lesson, students were asked high ordered, open-ended questions. The effectiveness of these “how” and “why” questions prompted students to actively engaged in classroom discussion and encourage students to compose high-ordered responses.

A final finding was the communication pattern observed during the science lessons. Lessons in which students demonstrated the most effective learning were those in which the teacher controlled the lesson with question, but teacher’s questions were guided by students’ questioning and ideas (Smart, J, & Marshall, J., 2013, page 261). Lessons that helped students to guide investigations in the classroom demonstrated more meaningful scientific discourse. An example was identified in a lesson that was exploring the concept of density. Students were given several aluminum soda cans to place in a container of water. A student’s observation of
their can floating while others’ sinking prompted the teacher to direct the class to analyze their can and compare results. This caused an extension that gave students the opportunity to further investigate by doing research at home in preparation of an in-class discussion the next day.

A weakness in this study is the possibility of researchers’ presence in the classroom influencing results. It has been observed in other studies that students’ engagement can sometimes become influenced by the presence of visitors in the classroom. It was not indicated if teachers provided their own observations that were used in the data collection for this study.

Implications discussed in this research included the teachers’ key role in in the process of promoting higher cognitive level thinking (Smart, J, & Marshall, J., 2013, page 266). A teacher without any prior practice in higher level questioning might need to be more aware and critical of their own skills. Remedies discussed included ways teachers can prepare or begin to learn by having a set of question prepared beforehand (Smart, J, & Marshall, J., 2013, page 265). Another way discussed that could better one’s practice included using higher ordered questions in journal activities. This practice suggests an increase in reasoning, justification and writing skills (Smart, J, & Marshall, J., 2013, page 266). A final opportunity for self-improvement of teaching skill included observing other teachers using higher order questioning in inquiry activities.

Knowledge diversity in the classroom

The purpose of this study was to investigate the connection in knowledge diversity and its impact on student engagement in the classroom. For this study, knowledge diversity is identified as the prior knowledge students have prior to entering the classroom/beginning the lesson. Student come from various educational background and have various learning style. This contributes to the diverse knowledge students may have about different subject matters. Two
categories of diversity were explored in this study; Biodemographic diversity (visible and observable characteristics) and task related diversity (individual attributes) were apparent (Jian Zhao, Lijia Lin, Jiangshan Sun, Xudong Zheng, & Jia Yin., 2018, page 756).

The classroom in this study was based in a junior high school in Shanghai. The groups observed in this study included 4-5 students. Students participated in an inquiry lesson that guided students to explore conductivity by building a circuit. Students had no prior knowledge on how to build a circuit but did know how a circuit works. At the end of the lesson, students filled out a demographics and engagement survey. Three scales were used to assess the lesson. The scales used were a behavioral, emotional and social engagement scale. The surveys given to students was a Likert type scale with points ranging from 1-7.

The first finding in this study explored the effects of biodemographic on students’ engagement. It was demonstrated that there was no correlation between gender and knowledge diversity (Jian et al., 2018, page 759). This was identified when students of mixed abilities and low prior knowledge contained a mixed number of students of each gender.

The next finding explored the effects of independent knowledge diversity on an individual’s engagement. One finding from quantitative data identified that students with prior knowledge scored higher on behavioral engagement than students with low prior knowledge (Jian et al., 2018, page 760). To further explore this finding, results of low prior-knowledge individuals was compared those in the low prior-knowledge groups to those in the mixed ability groups. Not including the performance of the high prior knowledges student equally distributed
within all groups, data showed that low-prior knowledge students scored higher in emotional engagement in the mixed ability groups rather than their peers in the low prior-knowledge group (Jian et al., 2018, page 760). These finding demonstrated the effectiveness of heterogenous grouping. Grouping students with low prior-knowledge with students with students of higher-knowledge improved behavioral, emotional and social engagement (Jian et al., 2018, page 761).

A weakness identified in the study included the lack of study on the effects of prior-knowledge and engagement in independent activities (Jian et al., 2018, page 761). It was suggested that this could provide control conditions that provided opportunity for further data analysis. Unfortunately, lack of materials did not allow such study.

Another weakness identified was the inability to compare qualitative data of the process in this study. The uneven mix of diverse prior knowledge (5 higher knowledge vs. 40 low prior-knowledge students) did not provide data collection opportunity that would have given accurate results (Jian et al., 2018, page 761).

An implication discussed was the approach in student grouping for effective classroom engagement. It was discussed that the amount of high prior-knowledge students does not affect engagements, as long as there is at least one student of higher prior knowledge.

Engagement in Science Classroom

Factors that affect classroom engagement in the classroom is researched in this study. Choice in activities possibly fostering student learning and engagement was explored in this study. Student engagement patterns lead the study to focus on the relationship of student engagement and choice of or type of activity used in the lesson.
This study included 12 classrooms of diverse races and socio-economic status. Data collected for this study included quantitative data analyzed from students. Researchers collected data about the students’ experiences using ESM model (Experience Sampling Method) (Schmidt, J. A., Rosenberg, J. M., & Beymer, P. N., 2018, page 27). Qualitative data was collected from observations. Hidden cameras recorded the lesson in each of the classrooms. This provided areas for collection of behavioral observations and quality of learning during random periods in a lesson.

Students surveys measured cognitive, behavioral and affective engagement. During various parts of the lesson, students identified if they had a choice on what they were doing at the moment. This meant if they had a choice in classroom activities. For instance, partnering, usage of materials, how or which activity to do and time spent on activities was identified by students (Schmidt et al., 2018, page 29). Majority of the responses collected (25%) happened during laboratory activities.

A finding demonstrated that students that students’ choice was included in 55% of activities and no student choice was found in 45% of activities observed in this study (Schmidt et al., 2018, page 30). A surprising finding was that students demonstrated extreme engagement results in both full engagement and low engagement during laboratory activities. Other activities demonstrated variable engagement, including low engagement in activities that were assessments and had summative grading.
Another finding was that individual work and lectures reported the lowest engagement/reluctance in students during this type of activity. Providing the students opportunities to choose during activities demonstrated an increase in pleasurable and full engagement in classroom activities (Schmidt et al., 2018, page 34). In turn, this led to meaningful learning in the classroom. Approval rating of students demonstrated that the power of choice fostered science engagement in the classroom.

A weakness in this study not discussed was the measurable values of academic success of the implementation of student choice in classroom activities. Students approval was discussed, and observation of meaningful learning engagement was identified. The statistics represented actual effective and long-term learning was not found/discussed in the study.

An implication discussed in this study included the connection between students’ cognitive engagement and behavioral engagement. This was not implied by data but instead by rationalization. Schmidt, Rosenberg and Beymer identify that student will only participate and want to learn when they can choose what they are learning. Therefore, having a choice results in effective learning in the classroom (Schmidt et al., 2018, page /35). The finding of this statement was not justified with data, rather, it was defended by classroom observational analysis of effective student engagement. Teachers identified that tasks offered for student selection all demanded high concentration and effort. This meant that no matter what activity student chose, significant learning was the outcome of these choices.
Science Classroom Inquiry with Simulations

Technology integration in the classroom is widely discussed in many studies. An aspect that has been investigated when integrating technology in the classroom is students’ perception of the use of simulations. In this study, students’ experience of the integration of virtual science simulations in the classroom and their believed ease of learning was studied. Students’ experience and quality of learning was measured in order to identify how effective the simulations are in the science classroom.

The students that participated in this study varied in prior knowledge of the contents used in the simulations. 29 middle school students and 59 high school students were part of this study. For this study, SCI- Simulations (Science Classroom Inquiry simulations) were used. Simulations presented had students choose scenarios through a virtual science experiment (Peffer, M. E., Beckler, M. L., Schunn, C., Renken, M., & Revak, A., 2015, Page 4). The simulations provided students the opportunity to pursue a chosen hypothesis and collect data. Students interpreted data and used it to justify their hypothesis. As students worked through these simulations, activity was recorded in a lab book that was used as observations for this study (Peffer et al., 2015, page 5).

Students’ learning experience with the use of science simulations was studied. Students reported that all simulations were helpful. At the end of the study, students completed a paper survey to provide feedback on their experience with the simulations. Students’ expressed an increase in learning quality from the use of simulations in the classroom. Students identified that they were able to experience what scientist do when researching and testing theories. Students
also indicated their realization the amount of work that is needed to study a problem and derive a possible solution (Peffer et al., 2015, page 9). Approximately 70% of student said that these simulations altered their perception of the scientific process (Peffer et al., 2015, page 10). These simulations helped students to engage in learning in a meaningful way that they were comfortable doing. The exact measure of learning was not measured. Instead, teachers measured students learning by students’ activity in the simulation and students’ experiences expressed in the survey (Peffer et al., 2015, page 12).

Simulations in this study supported student learning on the application of the scientific process. Students also reported that all simulations required significant though effort for completion. This enhanced new concept learned and help support students’ prior knowledge. Students connected concepts learned in simulations with other prior knowledge from other classes. In this study, a student expressed that a specific simulation expanded on a topic that they had learned previously in AP Biology (Peffer et al., 2015, Page 10). Students expressed strengthened scientific practice. This was supported by the ability to research a different hypothesis if data did not help solve the original problem (Peffer et al., 2015, page 11).

Implications discussed in this study included the measurable quality of students’ learning. Students expressed an increase in content learned and discussed their approval of the use of simulations in the classroom (Peffer et al., 2015, Page 13). The extent of the simulations’ effects on students learning was not specific. It is discussed that future studies can focus on specifically measuring quality of learning during the simulations. This was suggested in order to enhance this study further.
Research Support for Capstone Project

Game Simulations in the Physics Classroom

Besides computer simulations, this study integrates digital game simulations when introducing basic concepts of electromagnetism. In this study, the quality of learning was compared between a classroom enhanced with this simulation and a class that learned the unit traditionally. The traditional approach included multiple guided inquiry activities while the experimental group used a game called “supercharged” during the lab portion of the unit (Anderson, J., & Barnett, M., 2013, page 914). This simulation game was integrated in the lesson and provided opportunity for students to manipulate variables that helped them to observe the studied phenomenon.

Prior to conducting this research, students were interviewed in order to assess prior knowledge of charges. From this, students’ absence of knowledge about electromagnetic charges was identified (Anderson, J., & Barnett, M., 2013, Page 920). Post interviews were used in order to observe how students’ description of electromagnetic fields has changed.

One finding in this study was the quality of content understanding. Students in the classroom using the simulation outperformed the students in the traditional classroom. This finding was discovered when looking at the short-answered responses on an end of unit test (Anderson, J., & Barnett, M., 2013, Page 920). Observational data was also acquired from classroom observations of discussions. Comparison of pre and post interview responses identified difference in quality of explanations. Students whom used the simulations were able to explain the scientific phenomena studied in more depth than students in the class that didn’t use the simulation (Anderson, J., & Barnett, M., 2013, page 921). An important factor that led to this discrepancy was that student whom used the simulation explained concept from their experience
using the program. Unlike the experimental group, students in the traditional group relied more on using memorized concept in order to answer interview questions. Using simulations in this particular classroom demonstrated an increase in quality of learning and proved that the experience provided avenue for long term learning. A positive effect of quality of learning was seen when comparing students pre and post test results. Researchers in this study reported both an increase in traditional testing and in the explanation, students provided of the studied phenomenon (Anderson, J., & Barnett, M., 2013, page 923). Problem solving skills, visual representation and hands on experience helped student learn through play with this game for this unit (Anderson, J., & Barnett, M., 2013, Page 924).

Another finding in this study discussed was the altercations involving the use of technology in the classroom. Students can become easily distracted and can forget the purpose of the activity. The research reported students becoming off task when first playing the simulation (Anderson, J., & Barnett, M., 2013, page 923). This was remedied by having students fill out access logs that asked them to report finding from the simulation. This ensured that students remained focused and held them accountable for their use of the simulation.

Implications discussed in this study included the lack of “metacognitive” activities such as reflections in the video game simulation used in this study. It was suggested that the quality of assessment would be much meaning full if student learning was measure in game play rather than relying on students’ responses in the activity logs created (Anderson, J., & Barnett, M., 2013, 923). Assessment integrated directly in the game play can also make sure students remain on task and assure that there is positive learning happening during the lesson.

Another implication discussed was students’ perception of the simulation used in the unit. A concern identified was students not finding the simulation as not a learning experience.
Differentiation using Virtual Simulations

Different instructional strategies can help students develop scientific skills and scientific inquiry in the classroom. Two factors were studied in this research. One factor studied was the impact of teaching chemistry with simulation on student learning. The other factor studied was the effects of simulation integration on scientific inquiry.

This study took place in a chemistry classroom in a North American community university. As part of this study, the introductory chemistry classes that usually consisted of 33 students of various majors. Researchers collected observations for this professors’ integration of simulations in the classroom in a time span of 1.5 years (Khan, S., 2011, page 219). Qualitative data collected in this class used TPCK in order to gauge the extent and the effectiveness of the simulation integration in the classroom. Observations aligned student response with the GEM instructional strategy. GEM check for student ability in generating, evaluating and modifying scientific explanation.

One major finding was the use of simulations to support students understanding of chemistry phenomena studied in the classroom. The Chemsuite simulations were not used in place of lab experiments. Instead, these simulated experiments were used for students to manipulate experiments in order to understand the relationship between variables (Khan, S., 2011, page 226). These labs simulations help enhance student understanding of phenomenon studied during lab activities. Students performed lab experiments and then used the simulations to collect additional data for analysis. This prompted students to analyze their data and apply
observation to a new experiment set up. The simulations were also used to help students to observe details that are normally not observable when doing the physical lab. An example was when the teacher had students redo an experiment using the simulation in order for students to study the behavior of atoms under certain conditions that was not easily observable in the physical lab that was done (Khan, S., 2011, page 221).

Another major finding was the development of scientific skills and increase scientific inquiry using simulations in the classroom. Overall, it was observed that students generated, evaluated and modified relationships studied in the classroom (Khan, S., 2011, page 222). An example is seen when students were studying relationship between boiling point and molecular weight. Using the simulation, students explored the relationship of these two variables for various compound and created a general trend that explained the phenomenon (Khan, S., 2011, page 222). Students later revised this general trend when exploring hydroxyl groups and other molecules that tend to not follow the trend observed (Khan, S., 2011, page 224). Using the simulations and observations, students gathered that the bonds between molecules could be a reason for the anomalies in the trend of boiling points. Students continue to develop this understanding by further exploring variables effecting boiling points in order to create an overall concept to explain boiling points of molecules (Khan, S., 2011, page 224). Scientific inquiry was promoted when students kept returning back to the simulation and manipulating variables to support explanations created for phenomenon studied. In turn, this type of inquiry provided opportunity for students to have something to always refer to when explaining what they have learned rather than memorizing relationships/concepts in topics learned.

A strength in this research was the presentation of students’ development of thinking through this process. Students’ explanation of phenomenon was shown. It was also shown how
these explanations were redeveloped when students further explored concepts using the simulations and reanalyzed composed relationships.

An implication discussed in the study was the possible misconception that students may have about scientific data collection. The researcher discusses that students might believe data is easily attainable since data collection from these simulations can be done in under a lab period (Khan, S., 2011, page 226). This can be easily remedied by reminding students that scientist can spend years collecting data and exploring the same variables they are studying from these simulations.

Virtual Simulations in the Chemistry Classroom

Integration of simulations in the classroom have promised opportunity for active learning and gave the ability for teachers to visually clarify complex concepts to students. Integration of simulations in the classroom provides learning opportunities providing a virtual environment that provided an opportunity for hands on learning. A factor studied in this research is the effects of simulation integration in chemistry academic performance.

This study takes place in classrooms in New York. The overall length of this study was approximately 4 years. 15 classrooms from NYC public classroom that consisted of 361 students. The student population also consisted ELL students. The group of students in this study consisted of mixed learning abilities and of diverse cultural background. Observational data was collected from classroom visitation throughout the entire research. Quantitative data was collected from post/pre-test administered in the classroom.

The purpose of integrating the simulations was to facilitate an active and collaborative learning environment in the classroom. The teacher introduced the topic of kinetic molecular
theory with the use of simulations. The simulations were integrated in order to support the current model of levels used to study chemical phenomenon in the classroom.

One major finding was the academic improvement in the classroom. Research demonstrated that students developed deeper understanding of chemistry concepts with the use of simulations. Students demonstrated better comprehension of concepts by scoring substantially higher on posttest than classrooms that did not integrate simulations in the classroom (Plass, J. L., Milne, C., Homer, B. D., Schwartz, R. N., Hayward, E. O., Jordan, T., Verkuilen, J., Ng, F., Wang, Y. and Barrientos, J., 2012, page 416). Visually presenting the movement of molecules when boiling water helped students understand KMT at a deeper level.

Another major finding was the use of simulations to discuss real world examples in the scientific classroom. An issue discussed in the study was the loss of interest in sciences when teachers fail to discuss real world relating to the study (Plass, J. et al., 2012, page 397). An example discussed was the use of a simulation to enhance curriculum involving the kinetic molecular theory. The real-life example used was the exploration of what happens to molecules in boiling water (Plass, J. et al., 2012, page 401). The unit was introduced by discussing what happens when water is boiled. After discussion, students used a simulation to plot temperature during the phase changes of water. When first introduced, a narrative was used involving an everyday activity student can relate to (Plass, J. et al., 2012, page 401). This scenario was then explored in the molecular level by observing the relationship between temperature, kinetic energy and potential energy. Understanding this relationship gave opportunities and memorable learning experience that the teacher would later refer back to in future topics (Plass, J. et al., 2012, page 399).
An implication discussed in this research was the integration of a variety of simulation into chemistry curriculum. Possible opportunities of an effective sequence in integrating multiple simulations in various chemistry curriculum can prove useful for research. An interesting factor to explore is how student perform academically when using multiple simulations to support many units covered in this course. Students did exceptionally well when integrating simulations in the topic of kinetic molecular theory. The study could also benefit by studying how well students do academically in each individual topic. This could discover if simulations might show was improvement in certain topics versus others.

**Virtual Simulations in the Secondary Classroom**

Simulations can be integrated in the classroom to introduce virtually any concept that would otherwise be hard to show students. Virtual simulations helped students to learn in different environments and manipulate factors in this environment. For this study, a virtual simulation was used to present the topic of biological evolution to 11\textsuperscript{th} grade biology classes. The overall goal was to study how simulations effect students’ perception and conceptual understanding of the topic learned.

In this research, a “smart classroom” was used student the effects of simulation and student inquiry. The Evoroom simulation consisted of one that was easily manipulated in order to reveal or conceal factors from students. This simulation also projects the entire room. This gave the students the feel as if they were walking through the geographical location being studied. The topic studied in this research was biological evolution. Evoroom simulation was integrated in a 12-week program. Part of this this integration, students explored the rainforest as
field researchers, viewed the processes of different evolutions and then formulated explanations for the evolution of assigned organisms.

One major finding was students’ increase understanding of evolution after using the simulation. Students learned through scientific inquiry by exploring a multitude of organisms and how their evolution was affected by certain factors (Lui, M., & Slotta, D., 2012, page 73). Students demonstrated understanding through pre/post-test and explanation of scientific phenomenon. Students pretest median score was a 59. Post test score median was 79. This showed a major improvement in students’ understanding of evolution. Students were able to share thoughts and notes in this simulation. This gave the teacher the opportunity to formatively observe students’ observations throughout the simulation activity. The integration of this simulation helped increase understanding of a hard concept that is known for students to struggle in.

Another major finding was students’ perception of the use of simulations in the classroom. Students reported that visually exploring the rainforest and seeing the simulation of the different drivers of evolution was helpful in understanding these concepts. Students were easy recepctible to the simulation activities due to experience in everyday technology usage. Integration of this simulation demonstrated an increase in student engagement in the classroom. Students mentioned the appreciation of being able to research and “see” relationship between animals (Lui, M., & Slotta, D., 2012, Page 76). Students also appreciated the virtual environment Evoroom provided. Students loved interacting with this simulation. Students mentioned that it brought realism to the activity (Lui, M., & Slotta, D., 2012, Page 76). Students demonstrated an
increase in engagement in the classroom and expressed positive feedback of the integration of simulations in the classrooms. Students discussed the benefits they found in these integrations such as being able to visually see phenomenon.

Although students demonstrated basic to intermediate explanation of the different drivers of evolution, research showed that there was still room for improvement. Future implications to consider for this research would include the rigor of the activities associated with this simulation. The research discussed the benefits this strategy would gain from integrating scaffolding of activities (Lui, M., & Slotta, D., 2012, Page 77).

**Simulations and Students Understanding in Chemistry**

Simulations are useful for students to understand concepts that are otherwise not viewable with the naked eye. The simulation used in this study was created using QuickTime pro, Microsoft office PowerPoint and adobe flash player. These simulations were used in this study to explore how they would affect student understanding of chemical equilibrium. Using these simulations provided the opportunity for students to visualize phenomenon and learn to application of these concepts learned (Özmen, H., & Naseriazar, A., 2017, page 122). The designated concept that is being studied for this research is the topic on equilibrium. Researchers identified this topic to be a hard concept for students to understand (Özmen, H., & Naseriazar, A., 2017, page 121). In this research, the problem identified was that content learned in the traditional classroom alone was not enough.

This study was done in a university in Turkey. A total of 125 students participated in the study. 65 students were assigned as an experimental group and the rest were part of the control
group. This topic was covered in high school chemistry for these students. It was expected for students to have prior knowledge, but it was identified that students had many misconceptions. Each student recalled learning chemical equilibrium in high school chemistry but struggled understanding the concept. The experimental group had 6 simulations integrated into their curriculum. The concepts were taught in class and then reinforced with the simulations. Each simulation prompted students to explore different scenarios with chemical equilibrium (Özmen, H., & Naseriazar, A., 2017, page 125). Students were given scenario that required them to manipulate the system in the simulation, make observations and then explained what was happening (Özmen, H., & Naseriazar, A., 2017, page 126).

One major finding in this study was the change in students’ knowledge of this concept after using the simulation. Students demonstrated a weakness in understanding when applying knowledge to answer traditional multiple-choice pre-test. Students were then given the opportunity to study scenarios by using different simulations. Using the simulations, students successfully explained/understood chemical equilibrium. Both groups demonstrated an improvement in understanding. Students in the experimental group had higher mean scores than students in the control group (Özmen, H., & Naseriazar, A., 2017, page 126). Retention of student knowledge was measure using the ANCOVA model. A delayed test was used to measure how well knowledge was retained. Students demonstrated less knowledge loss in the experimental group in comparison to the control group (Özmen, H., & Naseriazar, A., 2017, page 127). This demonstrated that students that used simulations retained knowledge longer than students whom did not.

Another major finding was the use of simulations in addressing misconceptions about chemical equilibrium worked due to its interactive abilities. The simulations was beneficial
because students were able to see the microscopic behavior of particles in chemical equilibrium (Özmen, H., & Naseriazar, A., 2017, page 129). A misconception identified in by these interviews was the belief that the rate of the forward reaction is greater than the rate of the reverse reaction (Özmen, H., & Naseriazar, A., 2017, page 130). This misconception was identified in 65% of students in both the control group and experimental group.

Another misconception found was students’ belief that when adding substance to a reaction, the equilibrium will shift toward the added substance. 53-64% of students in both control and experimental group had this misconception (Özmen, H., & Naseriazar, A., 2017, page 130). These misconceptions were just a few from the many discovered in this study. Using these results, researchers guided students in the experimental group to test these scenarios in the simulations. The post-test result demonstrated a decrease in percentage for these misconceptions for both control and experimental group. The degree of decrease in these misconceptions were more significant in the experimental group than in the control group (Özmen, H., & Naseriazar, A., 2017, page 131).

A weakness discussed in this study included the availability of technology in the classroom. There were a total of 65 students and not enough computers for students to work independently. Instead, students took turns and worked in groups (Özmen, H., & Naseriazar, A., 2017, page 135). This simulations activity might have gone a lot easier if smaller groups were used or if technology ratio is 1:1.

An implication discussed was the data collection method used in the study. Although the pre/posttest gave opportunity for the analysis of students’ knowledge acquisition, integrating short response questions could make results more meaningful in identifying how much
information was retained by students. Open response questions would have required students to recall more information than when answering multiple choice questions.

*Molecular Modeling using Virtual Simulation*

This research discusses the use of simulations in a biology classroom. Just like in the chemistry classroom, the study identified the need for students to be able to visualize biological concepts in a molecular level. In this study, a simulation called VMD lite is used to present content to students. This simulation was used to help students visually study biomolecular structures (Lundquist, K., Herndon, C., Harty, T. H., & Gumbart, J. C., 2016, page 125). A benefit of the use of this simulation is the ability to integrate cross-cutting relationships in the classroom. This simulation aided in the possibility of incorporating chemistry and physics in biology curriculum (Lundquist et al., 2016 page 125). The research studied the effects of engagement and measure of students’ reception when integrating simulations in the classroom.

The study was done in 3 high school classrooms with students ranging from grade 9-12 in Atlanta, Georgia (Lundquist et al., 2016 page 125). This simulation was chosen for this study due its user-friendly attribute for a high school classroom. A google survey was used in order to measure students’ receptiveness of the simulation integration. Two objective questions were also used to measure students understanding of concepts presented.

One major finding was the effects of visual representation of concepts learned in classroom learning. In the lesson, students were learning about phospholipids and membrane diffusion. The simulation aided students to visually explore the cell and study the polar and nonpolar components of phospholipid molecules (Lundquist et al., 2016 page, 126). Students found that they understood concepts better from seeing it in 3D rather than the pictures in the
textbook (Lundquist et al., 2016 page, 127). Students also mention the amount of details observed in the simulation that was not readily observable in a standard image. Students were able to manipulate the macromolecules to make observations (Lundquist et al., 2016, page 127).

Another major finding was students’ receptiveness to the use of this simulation in the lesson. Students expressed an increase of intrigue when exploring the 3-dimensional models of the molecules. Students also expressed an increase in interest because they were able to see what is happening during cellular diffusion (Lundquist et al., 2016, 127). Like previously mentioned, students also enjoyed the amount of detail in the models versus the lack of detail in regular textbook images. Students’ views expressed in the survey showed an increase in student interest and engagement in the classroom.

A third major finding in this research was the importance of using simulations that are user friendly in the classroom. The simulation used in this study was easy enough to use that students did not require much instructions in using it (Lundquist et al., 2016, page 128). A weakness sometimes seen when using simulations is the degree of difficulty for students to use them. The study identifies students’ receptiveness increased due to ease of use of the simulation. Meaning, less time learning how to use the simulation and more time spent learning by using the simulation.

A weakness in the study was the measure of actual learning that happened while using the simulation. Students expressed how much they loved the simulation, but misconceptions were identified with the use of questions integrated in the simulation. This could be easily remedied by modifying lesson plan or simulation to cover and correct theses misconceptions.
An implication discussed in this study was the need to increase further study on the connection between the use of simulation and the quality of long-term learning. Not enough data was collected to determine the quality of learning that underwent in this study. This could be easily remedied by integrating a pre-test and post-test for a future study on the effectiveness of this simulation.

**Phenomenon Exploration and Data Collection with Virtual simulations**

In this study, a simulation called 2DE Tandem MS is used to help study single cell organisms. This simulation helped students with the manipulation and data collection of pre and post synthesis of proteins. Students can virtually study gel electrophoresis and peptide formation without the use of expensive laboratory equipment (Fisher, A., Sekera, E., Payne, J., & Craig, P., 2012, page 395).

This simulation was introduced in a biology classroom in a university. 21 students partook in this study. At the conclusion of the activity, students filled out a survey to express their experience and thoughts on the use on possible future improvements of this simulation. The implementation of this simulation was to efficiently practice the use of gel electrophoresis with the ability to redo a procedure with ease. An actual lab was used in conjunction with this simulation. Student used the simulation to explore the PI (the point where a molecule become electrically neutral) of an E. coli protein (Fisher et al., 2012, page 398).

One major finding students’ interest in this simulation due to its data collection capabilities. Students expressed that they enjoyed the amount of data that could be collected using the simulation for data analysis (Fisher et al., 2012, page 393). This simulation was suitable and effective for classroom integration due to it nature being able to be redone easily in
case of any errors. This simulation prevents many errors that would could not have been in an actual lab procedure (Fisher et al., 2012, page 395). Therefore, students are able to have proper results to analyze every time they use this simulation versus the physical procedure. This demonstrates how simulations could be used to collect data that would otherwise take scientist many years to do. This also demonstrated how simulations facilitated data collection by reducing the amount of classroom time needed to do this.

Another major finding in this study is the use of technology for exploring phenomenon not readily explorable in the classroom. Students studied proteins in a wet lab in a biology laboratory. Students studied different proteins but were not able to study the protein after being separated (Fisher et al., 2012, page 398). The researcher expresses the visual nature of this simulation. This simulation helped student visually see the separation of proteins using graph with pH values. Students were also enjoyed the ability of the manipulation of the process being able to select proteins from a massive database for exploration (Fisher et al., 2012, page 395).

A weakness discovered in the study are the complexity of data collection with minimal restrictive parameters. Students complained about the broad ability to study a multitude of proteins is intriguing, but that as an introduction to the lab, there should be a more specific goal when using this lab simulation (Fisher et al., 2012, page 395).

Another weakness discussed in the study was the amount of visual learning done in this simulation. Although the study suggested the visual nature of the simulation, students would benefit from actual “seeing” the molecules undergoing the synthesis. A future enhancement suggested by developer of this simulation was the integration of drawing of the molecules to work in tandem with the graphs that are generated during a protein synthesis (398).
Implications discussed in this study was the lack of user friendliness of this simulation. When selecting simulations to use in the classroom, it is important that is easy to use, and students can clearly gain the intended knowledge needed from it. Students complained about losing interest when the process became very repetitive and the lack of filters to assist in analyzing massive amount of data that was collected (Fisher et al., 2012, page 395).

*Computer Simulation and Student Engagement*

Simulations are useful tools in the classroom. Many researchers discuss the benefits of using simulations. Many discussions include how simulations enhance students’ understanding of phenomenon through visual representation. Unlike most studies, this research focuses on the pedagogy deliverance aspect of simulation integration. This research focuses on how the quality of a simulation can effect students’ engagement and learning outcomes. The study also focuses on the effects of the manner teachers integrate/present simulations in their lesson to students.

The research insinuates the need to study this type of use of technology due to many classrooms having availability of technology. Researchers go on to discuss the importance of assurance that students are properly learning how to use technology in the classroom (Cunha et al., 2014, page 77). This study takes place in two high school chemistry classrooms. Both teachers teach a lesson on the photoelectric effect. Two pHET models are used in this research. pHET is a company that offers a multitude of science simulations that can easily be integrated in the classroom. In the first lesson, students use a pHET simulation to study the photoelectric effect. Students then apply what they learn the next day to analyze a scenario. For the second lesson, students use the blackbody-spectrum pHET model. Both simulations are used in two different classrooms by two different teachers. The research examines how each teacher’s
deliverance of the lesson and simulation integration relates to the effectiveness in learning and engagement in the classroom.

The first finding in this research was the characterization of students’ productivity during the use of the simulation. Student demonstrated engagement when using interactive simulations that gave opportunity for students to visually see an outcome (Cunha, A. E., Saraiva, E., Santos, C. A., Dinis, F., & Lopes, J. B., 2014, page 83). In the observed classes, students were seen to become disengaged when teacher did not provide students challenging opportunities. The research discusses students being engaged in a classroom where the content was properly aligned to a simulation and an outcome was clearly visible (Cunha et al., 2014, page 83). Therefore, this provided students a clear goal and a purpose to what they are learning.

Another interesting finding was factors influencing teacher mediation of student engagement while using the simulations. The deliverance of the teacher correlated with how well students were receptive to the lesson. It was discussed in the analysis that students enjoyed being challenged (Cunha et al., 2014, page 83). The teacher in classroom A delivered a flawless lesson because she had authority of her classroom and properly paced her activities in order to maintain students’ attention (Cunha et al., 2014, page 84).

A final interesting finding were the weaknesses discovered in the study. Two classes with two different teachers were used in the study. Each teacher used a different teaching style during the study. On major finding that discusses would could decrease the success of using simulation in the classroom included teachers’ teaching approach. Giving too much away in the beginning of the classroom causes students to become disengaged (Cunha et al., 2014, page 84). This happens because the intrigue of “exploring” to discover concepts is no longer there. An example seen in this study was when teacher B would entice students with a challenge, but turned it into
traditional school work by giving too much information on how to explore using the simulations (Cunha et al., 2014, page 84).

An implication not discussed in the study was the effects of this simulation/teacher mediation on student grades. The study mentions an increase in student engagement and student understanding improvement. Quantitative data comparing pre and post simulation knowledge will demonstrate how effective this method would be in a science classroom.

*Virtual Simulations as a Representational Tool*

The relationship between teaching practice and student engagement is an important classroom aspect to study. Teacher practitioners research practices that can help enhance classroom instruction and increase student engagement. An emerging practice explored in many classrooms is the integration of computer-based inquiry in science curriculum (Hmelo-Silver, C. E., Liu, L., Gray, S., & Jordan, R., 2014, page 7). This study focuses on the relationship between student engagement and teaching practice while using diverse set activities, including online simulations.

Aside from hands on activities and a physical classroom, this study integrates the use of Netlogo biology simulation. Netlogo was used to simulate system dynamics in an ecosystem. This simulation was used for this study in order to promote an inquiry-based approach in the lesson. The use of this simulation provides opportunity for students to hypothesize, collect data and evaluate patterns (Hmelo-Silver et al., 2014, page 7).

The study includes a population of 145 middle school students. Students’ demographics include various diverse background and economic status. Two models were used in this study; fish spawn model and nitrification process (Hmelo-Silver et al., 2014, page 10). This study
focuses on the effectiveness of these simulators and how the teachers’ deliverance/usage of simulations can benefit the classroom (Hmelo-Silver et al., 2014, page 10). The study discusses the ability of integrating multitude of open-ended questions that can increase the complexity of content learned in classroom. The possibility of students using simulations as evidence to support claims increases student learning and increase effectiveness of using these simulations (Hmelo-Silver et al., 2014, page 10). In order to support the use of this simulation in this classroom, teachers attending professional development that helped students

One major finding discussed in the classroom is the importance of preplanning before using simulations in the classroom. The study discusses observation made in a classroom where this application was least effective. This was observed when the teacher spent more time giving instructions versus the inquiry aspect of the activities (using open ended probing questions) (Hmelo-Silver et al., 2014, page 8). The teacher which demonstrated the higher improvement of student engagement and content knowledge was the one whom scaffold instruction efficiently in the classroom. This particular teacher helped students explore all variables and their relationships in the aquarium ecosystem by designing an experiment (Hmelo-Silver et al., 2014, page 18). The teacher’s approach was to ask multitude of open-ended questions that prompted students to think and ask questions. It also guided students’ direction of exploration when using the simulations (Hmelo-Silver et al., 2014, page 18).

Another major finding was the effectiveness of the integration of NetLogo in classroom instruction. Data suggests a large increase in student knowledge after exploring the simulation. This is seen when comparing pre and post-test data and seeing that 63-77% of students demonstrate an increase in knowledge about the studied ecosystem (Hmelo-Silver et al., 2014, page 16). Students in the more effective classroom explored using simulations, created
experiments and then revisited topics in discussion and used evidence for reasoning in these discussion (Hmelo-Silver et al., 2014, page 18).

Teaching implication of question style in the lessons was discussed. This was a repeat concept discussed but not in full detail. At various point of the research, the more successful classroom uses open-ended questions rather than yes/no questions for probing student discussion (Hmelo-Silver et al., 2014, page 21). The lower performing classroom asked many questions that were similar to the worksheets used in the classroom. Examples from a low performing class included questions like “did you start figuring out that key, do you have an idea on some of them?” (Hmelo-Silver et al., 2014, page 21). Although students remained engaged, the rigor in learning was absent when these kinds of questions were used. Meaning, these kinds of questions fail to prompt students to analyze scenarios and use as evidence for supporting claims.

Supporting Reasoning with Virtual Simulations

Simulations give teachers the opportunity to help students get a deeper understanding of scientific concepts. This is achieved because simulations helped students explore concepts that they could not explore in the classroom. A large part of chemistry consists of visualizing molecular level of phenomenon. Another part of science is scientific discourses. Through different interactive activities students can learn how to develop their vocabulary when expressing scientific explanations and rationales. The research suggest that simulations can help show this to students (Levy, D., 2012, page 703). This research studies the effects of integrating chemistry simulations in the classroom.
For this study, 600 students participated from grades 9-12. The model used in this simulation was called “phases of matter and change”. The simulation used was part of a research project at Berkley that created a series of “Wise” science simulations. This simulation prompted students to go through modules that gave them opportunity to manipulate different simulations and answer analytical questions about the scenarios studied in the simulations (Levy, D., 2012, page 703). Student progress was measured by collecting students’ response to the analytical questions and tracking progress of learning (Levy, D., 2012, page 706).

One major finding in this study was the positive social interaction that occurred when students used these simulations. Researchers identified the meaningful conversation between students while using the simulation in pairs (Levy, D., 2012, page 706). Students working in pairs helps students practice scientific thinking by speaking thought out loud. Working in pairs helped students learn and practice how to communicate scientific reasoning (Levy, D., 2012, page 707). This in turn also helped students practice scientific discourse and gave opportunity for long term learning. This is suggested because students explaining observed phenomenon in different scenarios helped students show competency rather than memorization of concepts.

Another major finding in this study was the increase of molecular rationale about molecular behavior of atoms and increases scientific discourse. Students demonstrated an increase of understanding on what the molecules are doing during a phase change. Students were able to identify during the pretest that molecules move more during a phase change. After the simulation, students were able to explain in a post test that movement breaks intermolecular forces between molecules during a phase change (Levy, D., 2012, page 709). Scientific discourse was shown by the quality of responses given by students. All responses that students answered during the post-test required students to use vocabulary word related to molecular movement and
phase change. Research identifies that students increase the use of these words after using simulations (Levy, D., 2012, page 711). An example of scientific discourse was when students responded “in a solid, the molecules are more compact. Then as they turn into a liquid or gas, they become farther apart” or explained movement breaking intermolecular forces for gases to escape (Levy, D., 2012, page 711). Students were able to also explain that “intermolecular forces were stronger or weaker” depending on the phase it is in (Levy, D., 2012, page 711).

An implication not discussed in this research paper is the individual analysis of student understanding. During the simulation activity, students worked together to explore. The pre and post-tests were done in pairs as well. This method lacked providing students’ independent quality of learning from the simulation. Another implication was the amount of student using the highest order of response quality still remained low. Although students understood that molecules moved apart/closer during phases changes, some students still failed to completely integrate a discussion of intermolecular forces (Levy, D., 2012, page 710). The number of students using that rationale increased but not enough to say that most students were considered to demonstrate the highest scientific discourse.

Virtual Simulations and Conceptualization of Rigorous Concepts

Simulations prove useful as a tool to help students understand rigorous concepts in the classroom. Simulations help achieve this by providing the opportunity for students to virtually explore visually and interact with properties they could not normally be able to in the physical classroom. This study discusses the benefit of using simulations to teach electron transport chain.

In this study, multiple simulations were created and given to 10 high school students. These simulations were created by using adobe flash cs3 professional (Teplá, M., & Klimová,
Each simulation was created to help students understand the processes behind electron transports. These simulations also integrated a quiz and a posttest to measure students understanding. Data collection for this research included a questionnaire teacher took after using the simulations in the classroom.

One interesting finding was the ability to use simulations to limit misconceptions in a given topic. In the study, researchers created the simulations to address common misconception students have with electron transport (Teplá, M., & Klímová, H., 2015, page 293). An issue student had in understanding electron transport is the redox process that is part of it (page 297). The simulation helped students by visually illustrating the electron transport process to students. Results from the survey revealed that many teachers agree that the simulation absolutely “sufficiently illustrated” content and it was easy for students to comprehend the topic presented (Teplá, M., & Klímová, H., 2015, page 298). The simulations nicely integrated illustrations from the macroscopic view all the way down to the microscopic view of the electron transport process. An example includes an image demonstrating the metabolic process of the breakdown of nutrients (macroscopic) to the scheme of “the mitochondrial electron transport” (Teplá, M., & Klímová, H., 2015, page 297). The simulation helped keep students engaged while learning which in turn increased student understanding. Teachers expressed that these simulations helped motivate students and kept students’ attention during the lesson (Teplá, M., & Klímová, H., 2015, page 298).

Another interesting finding was the effects of using simulations in the classroom on quality of student learning and the opportunity to assess the simulations’ effectiveness. The simulation included multiple points for the teacher to assess student understanding. At the end of the simulation, students took a test that allowed the teacher to display whole class results (Teplá,
M., & Klímová, H., 2015, page 297). This helped the teacher to assess understanding in the classroom as a whole. Teachers expressed in the surveys students whom used the simulations achieved better learning outcomes than students whom learned in the traditional classroom (Teplá, M., & Klímová, H., 2015, page 298). This means that the simulation helped students understand and meet more learning objectives set in the classroom using the simulation versus the traditional classroom. This finding also supports that simulations help increase student test grades.

A third finding was the students’ acceptance and willingness to use the simulation in the classroom. Teachers expressed that the simulation were easy to use, and students’ interest/attention increased (Teplá, M., & Klímová, H., 2015, page 298). This means that the use of this simulation in the classroom enhances learning due to its user friendly and captivating feature of it.

An implication not discussed in the study is the extent of how effective the simulation was on students test grades/understanding. The researchers analyzed the survey responses given by the teachers. This failed to give a concrete support to the correlation between simulation usage and student understanding. Although, the teachers report an increase of students’ quality of learning in the classroom, it fails to provide a numeral comparison of students’ assessment performance to gauge exactly how much of an improvement the simulations provide. This means that student data would enhance this study.
Virtual Simulations and Micro-macro concepts understanding

The study of matter and its properties is an essential concept in chemistry. These properties help explain many observed phenomena. This study seeks to explore the benefits of using simulation to support a complex approach in teaching matter.

This study takes place in a 7th grade science classroom in Israel. 104 students participated and a majority (70) were boys. The students were split up into two groups. One group studied matter using a normalized approach while the other group use the complex approach. Students reflection of the processes was recorded from student interview.

One major finding was the benefits of using the simulation to support a complex approach in the learning process. The purpose of a complex approach for this unit is the idea that this method can help students understand concepts in a much deeper level. The study outlines that students can study the mechanisms that drive studied patterns rather than just learning about the patterns alone (Samon, S., & Levy, S., 2017, page 986). The simulation helped students choose how in-depth the want to study the particular phenomenon. This supports the complex approach because students studied the forces (both macroscopic and microscopic) behind phase changes and different forms of matter (Samon, S., & Levy, S., 2017, page 1001). Students were able to explore how pressure, temperature, agitation and volume can affect molecules at different levels. Students demonstrated deep understanding of pressure that they were able to explain the effects of pressure in both a basketball and syringe using the simulation (Samon, S., & Levy, S., 2017, page 1003).

Another finding in this study is the ability of using a simulation in complex approach method to reinforce learning and simplify systems for students. The simulation gave students the opportunity to study a specific part of a system (Samon, S., & Levy, S., 2017, page 1001). This
helped students investigate the properties of the individual components and its interaction/contribution with the rest of the system. Using simulations to support complex learning also helped reinforces student learning. Students had the opportunity to practice what they learned. Students were able to study different scenarios under different conditions (Samon, S., & Levy, S., 2017, page 1001). This proved beneficial because students can learn complex topics and reinforce learning by applying and practicing in different scenarios. Students in the complex approach group demonstrated a substantial understanding of rigorous objective versus only 42% of the normalized group (Samon, S., & Levy, S., 2017, page 996). Students were asked about the behavior of gases and demonstrated different belief of gas molecules in a balloon. Before the simulations, students believed that the gas molecules added to a balloon would sink to the bottom (Samon, S., & Levy, S., 2017, page 998). After the simulations and lessons, students were able to identify that particles will have “homogenous” distribution in the balloon (Samon, S., & Levy, S., 2017, page 999). This demonstrated that the complex approach using simulations helped rectify misconception in student understanding.

An implication of this study discussed included the short time student learning was observed. The study discusses that many students benefited from the complex approach. Due to limited time, the quality of learning was not observed. In other words, it could not be determined if students retained what was learned from this teaching approach. A secondary implication could include students’ background knowledge. The study does not discuss how much background knowledge students had on molecular properties of matter. Although responses for pre and post scenarios were present, this was only for 5 students and it did not represent the entire group. This would help enhance the study because it can help accurately determine how
much student truly did learn from this approach and identify common misconception found in
students understanding about matter.

**Virtual manipulatives and Students Understanding**

Technology offers options for measurement and testing in the classroom. Having access
to technology gave students the opportunity to test variables in an experiment that would
normally require expensive equipment or that would take a long time to do. In this study,
researchers explore the use of virtual manipulatives in the science classroom. The overall goal
was to study how the blended use of virtual and physical manipulatives affect learning in the
science laboratory.

The study takes place in a university in Cyprus. 70 undergraduate students enrolled in a
physics class participated. The concept being studied in this research is of light and color
(Olympiou, G., & Zacharia, Z. C., 2011, page 24). The virtual simulations used for this study
was called optilab. Optilab, a virtual laboratory, prompted students to design their own
experiments and gave students options for more data collection.

An interesting finding in this study was the benefits of using virtual manipulatives. The
research discusses the need different benefits each type of manipulative brings into the
classroom. One benefit explored was the quality of learning students receive from virtually
manipulating objects. The study goes further to discuss the scaffolding and flexibility of using
virtual instruments. Students were able to perform the same experiment as the students in the
physical only laboratory class but had more opportunities for learning and less room for errors
This is seen when students were able to explore more examples than students in the physical only classroom (Olympiou, G., & Zacharia, Z. C., 2011, page 25). Using the virtual manipulatives in the laboratory helped students to manipulate factors that physical manipulatives were limited in. Students explore more color combinations offered in the virtual simulation that the physical tools were not able to offer (Olympiou, G., & Zacharia, Z. C., 2011, page 33). The teacher was able to scaffold instruction by following laboratory using physical manipulatives with the simulation as a method to reinforce learning (Olympiou, G., & Zacharia, Z. C., 2011, page 33). This was observed when students used the simulation to further explore additional color combinations outside of those done in the physical classroom (Olympiou, G., & Zacharia, Z. C., 2011, page 25).

Another benefit discussed was an increase in students’ learning when using both virtual simulation and physical tools for experimentation. Students’ learned more when using both instead of just physical manipulatives. Researcher compared post and pre-assessment for 4 exams. The comparison included the classroom using both the virtual and physical manipulatives, a classroom using physical manipulatives only and a classroom using virtual manipulatives. Students using both had higher exam grades than those whom did not (Olympiou, G., & Zacharia, Z. C., 2011, page 37). In all three classrooms there was growth in exam grades. This indicated that using any kind of manipulative helped students learning. The data proves that using both types of manipulatives provided students the opportunity to explore all aspects that both had to offer (Olympiou, G., & Zacharia, Z. C., 2011, page 26).
An implication discussed in this study was the importance of using both types of manipulatives in the classroom. Like physical manipulatives, virtual manipulative still had their limitations. Virtual tools did not give the opportunity to students to explore factors that contribute to experimental error or factors that give a more memorable experience from physically exploring it. An example discussed was the immense detail students remembered when using a physical pulley in an experiment versus a virtual pulley (Olympiou, G., & Zacharia, Z. C., 2011, page 25). Factors that make it ideal to use both include that these manipulatives complement each other by improving areas the other lacked. An example where this is seen was when students used physical tools to do the experiment and then used the simulation to experiment with more examples not readily physically available to the class (Olympiou, G., & Zacharia, Z. C., 2011, page 25).
Chapter 3 – Project

Unit- The atom

Intro to the atom
⇒ Original Lesson Plan

In the original lesson, students were given a piece of aluminum foil and asked to rip it into smallest piece they possibly could make. Students were then told to imagine that something that small is an atom of aluminum. Students worked in groups to compose definitions of the atom. This was a great way to introduce students to the atom. Students often struggle with understanding just how small an atom is.

⇒ Supplemental simulation activity and rationale

This simulation about matter provided a great introduction for students. Giving students the opportunity to create a meaningful understanding of matter and atoms. The simulation provides the opportunity for students to watch as the simulation zooms in from a grain of coffee and someone’s class notes (Figure 1) to an atom of carbon (Figure 2). Studies have shown that integrating simulations that show or demonstrate small scale concepts that students do not normally see help with long term learning (Özmen, H., & Naseriazar, A., 2017, page 127). This simulation helps student rationalize scale by starting with known objects before zooming in.

For the following activity, students use the structure of matter to introduce the concept of the atom.

Students outcome:
- Students will create a definition for an atom
- Students will complete an activity about the parts of an atom.
<table>
<thead>
<tr>
<th><strong>Title:</strong></th>
<th>Matter and the atom</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NYS Chemistry Standard:</strong></td>
<td><strong>Key Idea 3:</strong> Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.</td>
</tr>
<tr>
<td><strong>Supplies and Resource</strong></td>
<td><a href="https://learn.genetics.utah.edu/content/cells/scale/">https://learn.genetics.utah.edu/content/cells/scale/</a></td>
</tr>
<tr>
<td><strong>Key Questions</strong></td>
<td>How does matter and the atom relate?</td>
</tr>
<tr>
<td><strong>Summary of Activity:</strong></td>
<td>Students can zoom in and out from microscopic to macroscopic substances. Students can see that atoms are the basic composition of matter. This is an ideal simulation to include in the beginning of the unit as part of a class discussion. You can ask students to explain what an atom is based on what they observed from the simulation.</td>
</tr>
<tr>
<td><strong>Misconceptions addressed</strong></td>
<td>Students have a hard time visualizing the atom (Cokelez, A., &amp; Dumon, A., 2005).</td>
</tr>
</tbody>
</table>
Introduction to subatomic particles

⇒ Original Lesson Plan

In the original lesson, a video was shown to introduce the subatomic particles. This activity was followed with a worksheet and a guided practice on how to draw atoms of a chosen element. As an assessment, students would demonstrate competency by drawing the atom of a given element.

⇒ Supplemental simulation activity and rationale

![Build an Atom](Image)

*Figure 3Atom building simulation*

A pHET simulation about the atom was found to supplement this lesson very well. In order for learning efficiency, guiding prompts and questions were added to keep students on track. The simulation is interactive and provides students a choice of building atoms or playing a game. The simulation can also be used as a follow up activity for students to review at home.

For the following activity, students use the “build an atom” simulation to practice building atoms and recognizing the difference between atoms of different elements. The atomic structure and the relationship between the subatomic particles are the building stone for understanding isotopes and oxidation charges.

This activity helps students by:

- providing students the opportunity to learn about the relationships between the subatomic particles by manipulating a model on pHET.
- Helping students formulate explanation of charges and how an atom become ions.

This simulation has multiple variable that students can manipulate. This is an example of where long-term learning can take place. Students understanding will be more meaningful because they will be able to understand concepts by creating relationships between the variables (Samon, S., & Levy, S., 2017, page 1001).
Students outcome:

- Students will recognize that changing number of protons changes the element represented.

- Atoms of an element are stable when there is an equal ratio of proton and neutrons.

- Changing number of electrons makes an atom an Ion.

- Increasing the number of neutrons makes the nucleus unstable.

<table>
<thead>
<tr>
<th>Title:</th>
<th>Build an atom!</th>
</tr>
</thead>
</table>
| NYS Chemistry Standard: | 3.1a The modern model of the atom has evolved over a long period of time through the work of many scientists.  
3.1b Each atom has a nucleus, with an overall positive charge, surrounded by negatively charged electrons.  
3.1c Subatomic particles contained in the nucleus include protons and neutrons.  
3.1d The proton is positively charged, and the neutron has no charge. The electron is negatively charged.  
3.1f The mass of each proton and each neutron is approximately equal to one atomic mass unit. An electron is much less massive than a proton or a neutron. |
| Supplies and Resource | pHET simulation: https://phet.colorado.edu/en/simulation/build-an-atom |
| Key Questions | What are the relationships between the subatomic particles?  
How do you differentiate between the different subatomic particles?  
How did the pHET simulation help you visualize the relationship between the subatomic particles. |
| Summary of Activity: | This activity helps students to build their own atoms for a given element. This is done using pHET simulation. Students can use the simulation to see what happens when you add/take away electrons and add/remove protons. This supports the idea that changing the number of protons changes the element. This also introduces ions/charges of atoms. |
Gold foil's experiment

⇒ Original Lesson Plan
In the original lesson plan, students reviewed slides or watched a video to research and fill in a chart about the different models of the atom. This activity was followed by showing the students Rutherford’s Gold foil experiment and JJ Thompson’s Cathode ray. After watching the videos students answer questions on a worksheet like in the image below (Figure 4).

**Task III The Experiments**
Vital information was gathered by means of experiments that were conducted by scientists leading us to new discoveries that are still important to us today.

**Resources:** Watch a video of the experiments.
*Thomson’s Cathode Ray Tube* [https://vimeo.com/135823152](https://vimeo.com/135823152)
*Rutherford’s Gold Foil Experiment* [https://vimeo.com/139369896](https://vimeo.com/139369896)

Give a brief explanation of the experiment listed; the scientist involved. Answer the questions that follow.

a. **Cathode-Ray Tube**

   **Scientist**

   **Explanation of Experiment**

   ![Cathode-Ray Tube Diagram]

1. How do the conclusions tie in with scientific knowledge you already have?

b. **Gold Foil Experiment**

   ![Gold Foil Experiment Diagram]

   **Scientist**

   1. How did Rutherford disprove Thomson’s Plum Pudding Model?

   **Figure 4 Current worksheet**
Supplemental simulation activity and rationale

Figure 5 Repulsion of alpha particles

This simulation gives students the ability to manipulate the number of Alpha particles are shot toward a sheet of gold foil. This simulation is ideal for this lesson because it helps students to visually see and manipulate variables in for this experiment. Students can use this simulation to explore in detail of what Rutherford discovered rather than reading about it or watching a video about it. In other words, students will learn by doing.

Students can visualize the repulsion between the alpha particles and the nucleus of the gold foil experiment in real life. Students can observe particle passing through empty space. This activity helps students by:

- Helping them formulate explanation of the charge of the nucleus.
- Explain what experimental predictions the model makes.
Studies have discussed the challenges students face in developing connections between macroscopic and microscopic levels (Chao et al., 2015, page 29). Using this simulation, students can visually see the electromagnetic repulsion between alpha particles and the nucleus. Students can also observe the “empty” space in the atom.

For the following activity, students use the “Rutherford Scattering” simulation to perform the gold foil experiment.

**Students outcome:**

**Students will:**

- *Hypothesize what happens when the alpha particles are shot at the gold foil.*
- *Observe that the alpha particles are reflected from the nucleus. Nucleus is positively charged.*
- *Observe that many alpha particles went through the atom, this means the atom is mostly empty space.*

<table>
<thead>
<tr>
<th>Title:</th>
<th>Gold Foil Experiment</th>
</tr>
</thead>
</table>
| **NYS Chemistry Standard:** | 3.1a The modern model of the atom has evolved over a long period of time through the work of many scientists.  
3.1b Each atom has a nucleus, with an overall positive charge, surrounded by negatively charged electrons.  
3.1c Subatomic particles contained in the nucleus include protons and neutrons.  
3.1d The proton is positively charged, and the neutron has no charge. The electron is negatively charged. |
| **Key Questions** | How would you explain the interaction between the alpha particles and the atom of gold?  
What conclusions can you make from this experiment? |
| **Summary of Activity:** | In this activity, students will perform the gold foil experiment. Students can freely manipulate the number of alpha particles that are shot at the gold foil. Students will then answer questions based on what they observed. |
| **Misconceptions addressed** | Atomic 'empty space' and atoms as 'hard spheres' |
Electrons - Excited state

⇒Original Lesson Plan
In the original lesson plan, students used a ladder drawing to visualize the energy levels in an atom. In order to discuss ground state and excited state a video was shown of a puppy that become really excited and then eventually crashes. Students were then asked to formulate an explanation of how electrons could possibly act in the same way. Students already had knowledge of finding the electron configurations of specific atom.

Discussion activity in original lesson:
Discussion question:
• What happened when the water turned on? How would you describe the puppy’s energy level at this point?
• What happened when the puppy was done playing? How would you describe the puppy’s level at this point?
• Electrons function in the same manner. As a group, formulate an explanation of how electrons go between ground state and excited state.

⇒ Supplemental simulation activity
Exciting Electrons

Figure 6 Wave nature of electrons

This simulation helps students to manipulate the amount of energy given to the electron. This simulation gives students the opportunity to visually see what happens to energy as an electron goes between ground state and excited state. A benefit of adding this simulation into the lesson plan is the line graph that shows the wave nature in which the energy is being released in (figure 6). This can be discussed to students that it represents electromagnetic radiation. This activity can then be followed with a lesson on emission spectrum. Ideally, this works because
students will build on their observations from this activity to learn that the electromagnetic radiation release is in the form of visible light.

Students can visualize the wavelike emission of energy from the electron as it returns to ground state. This activity helps students by helping them formulate what happens to energy as an electron returns to ground state and visually see the wave-like emission of energy that electrons release.

Studies have discussed the challenges students face in developing connections between macroscopic and microscopic levels (Chao et al., 2015, page 29). Using this simulation helps students to visually see electromagnetic repulsion between alpha particles and the nucleus. Students can also observe the “empty” space in the atom.

For the following activity, students use the “Excited electrons” simulation to observe energy levels for excited electrons.

**Students outcome:**

**Students will:**

- **Hypothesize what happens when electron go from excite to ground.**
- **Observe that electrons release energy in the form of electromagnetic waves.**

<table>
<thead>
<tr>
<th>Title:</th>
<th>Excited Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYS Chemistry Standard:</td>
<td>(3.1k) When an electron returns from a higher energy state to a lower energy state, a specific amount of energy is emitted. This emitted energy can be used to identify an element.</td>
</tr>
<tr>
<td>Key Questions</td>
<td>How would you describe the behavior of electrons?</td>
</tr>
</tbody>
</table>
| Summary of Activity: | In this activity, students will use a simulation to observes what happens to an electron when energy is added. Students will be instructed to do the following:
  - Add any amount you would like to the electron.
    - After a few seconds, describe what happens to the electron.
    - How does the electron return to ground state?
    - What observations can you make about the energy emitted from the electron?
    - Compose a statement that explains what happens to energy as an electron goes from excited to ground state.
  - This can be shown to students before introducing emission spectrum. Teachers can tell students that the wave-like energy emitted from electrons is the visible light seen in the emission spectrum. |
| Misconceptions addressed | Atomic 'empty space' and atoms as 'hard spheres' |
Isotopes

⇒ Original Lesson Plan

In the original lesson plan, Students read a passage about C-14. Students then expanded a kernel sentence to include why C-12 and C-14 are isotopes.

Expand the following sentence to using information from the article.
They are isotopes.
Who/what?
Why?
Completed sentence:

Anticipated results include:
C-12 and C-14 are isotopes because

Discussion activity in original lesson:

Discussion question:

• Write the protons and neutrons for both Carbon 12 and Carbon 14, how do they differ?

• Carbon-14 is an isotope for Carbon- 12. Compose a definition for isotopes.

This activity is followed by students defining isotopes, atomic mass and mass number.

A few concerns that arise from this activity is that student still seem to confuse the difference between atomic number and atomic mass and mass number for isotopes. Students also sometimes believe that the nuclei are different and therefore that makes them isotopes. A suggested solution would be an interactive simulation that demonstrate the difference between concepts confused relating to isotopes.

⇒ Supplemental simulation activity and rationale

The suggested activity would be a simulation by pHET that is interactive and can help students understand the difference between terms involve in isotopes. This simulation can be used for as a guided inquiry to investigate different isotopes and their abundance. Students can visually see the difference between atomic mass and mass number (figure 7). Students can also explore the percent abundance of isotopes as they manipulate the number of neutrons in chosen elements (figure 8). This activity helps students visualize the vocabulary discussed in the unit.

Studies have shown that using simulations help students
Students outcome:

Students will:

- Investigate the different isotopes
- Formulate definition of isotopes based on observations made from simulation.

<table>
<thead>
<tr>
<th>Title:</th>
<th>Excited Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NYS Chemistry Standard:</strong></td>
<td></td>
</tr>
<tr>
<td>(3.1n) xi given an atomic mass, determine the most abundant isotope</td>
<td></td>
</tr>
<tr>
<td>xii calculate the atomic mass of an element, given the masses and ratios of naturally occurring isotopes</td>
<td></td>
</tr>
<tr>
<td><strong>Supplies and Resource</strong></td>
<td>Simulation: <a href="https://phet.colorado.edu/en/simulation/isotopes-and-atomic-mass">https://phet.colorado.edu/en/simulation/isotopes-and-atomic-mass</a></td>
</tr>
<tr>
<td><strong>Key Questions</strong></td>
<td>What are isotopes?</td>
</tr>
<tr>
<td><strong>Summary of Activity:</strong></td>
<td>In this activity, students will use a simulation to investigate different isotopes.</td>
</tr>
<tr>
<td></td>
<td>Discuss which isotopes were found to be abundant. Students can discuss how the different isotopes differ in subatomic particles.</td>
</tr>
<tr>
<td></td>
<td>This can be shown to students before introducing calculations of average atomic masses or isotopes.</td>
</tr>
<tr>
<td></td>
<td>Alternatively, Students can calculate the average atomic mass of an element by investigating different isotopes of that element. This can be done by removing or adding neutrons.</td>
</tr>
</tbody>
</table>
Unit- Nuclear Chemistry

Fission

⇒ Original lesson plan

In the original lesson plan, students watched a video about a fission reaction. During the video, students would answer questions on this type of reactions.

How would you define nuclear fission?

Write an equation representing nuclear fission.

What are some real-life applications for nuclear fission?

Why does the nuclear fission of uranium-235 become self-sustaining?

Students would write down the equation for a fission reaction of Uranium. One of the reasons this part of the lesson needed to be enhanced was the fact that students need to understand the role each element and radioactive particle had in this reaction. A simulation was found that provided students with a better understanding of how this particular fission reaction becomes self-sustaining.

⇒ Supplemental simulation activity and Rationale

Figure 9 Uranium nucleus

Figure 10 Uranium atom
This simulation gave students the opportunity to observe a fission reaction at a microscopic level. This simulation helps students to visually see the decomposition reaction of Uranium-235. A benefit of adding this simulation into the lesson plan is the visual illustration of an unstable Uranium atom releasing a neutron and two new elements. This simulation can either supplement or replace a video showing this reaction because students can observe the entire reaction and compose a narrative for what they are observing. Having students come up with a narrative for the simulation helps the student remember the content better.

For the following activity, students use the “Fission” simulation to observe a fission reaction for Uranium-235.

This activity helps students by:
- Being able to visualize the reaction.
- Using a visual to differentiate between fission and other reactions.

A common misconception amongst students during this topic is the belief that atoms cannot change to other elements or that radioactive particles remain radioactive forever (Nakiboglu, C., & Tekin, B., 2006). This simulation demonstrates that during a nuclear reaction, new elements are formed. The simulation also shows that the product in the nuclear reaction are new elements that are no longer radioactive.

**Students outcome:**

**Students will:**
- Create a narrative for the fission reaction.
- Rationalize why the reaction is sustainable from what was observed in the simulation.
<table>
<thead>
<tr>
<th>Title:</th>
<th>Fission reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NYS Chemistry Standard:</strong></td>
<td>4.4f Nuclear reactions include natural and artificial transmutation, fission, and fusion.</td>
</tr>
<tr>
<td><strong>Supplies and Resource:</strong></td>
<td>Simulation: <a href="https://www.edumedia-sciences.com/en/media/491-fission">https://www.edumedia-sciences.com/en/media/491-fission</a></td>
</tr>
</tbody>
</table>
| **Key Questions**             | What is a fission reaction?  
|                               | How are fission reactions sustainable? |
| **Summary of Activity:**      | In this activity, students will use a simulation to observe during a fission reaction. Students will be instructed to do the following:  
|                               | ● Watch the simulation, pause at various parts of the video to do the following:  
|                               |   ○ Create a narrative for the reaction that is being observed.  
|                               |   ○ Discuss why this reaction is self-sustainable.  
|                               |   ○ Students will compose a nuclear reaction to represent a fission reaction.  
|                               | **Observable outcomes:**  
|                               | ➔ Students should identify that a neutron bombards a Uranium-235 atom.  
|                               | ➔ Students should describe that the reaction releases 2 new **stable** elements and 3 neutrons.  
|                               | ➔ Students will rationalize that the reaction is self-sustainable because the release of 3 neutrons cause a chain of fission reactions to occur when it collides with more uranium-235. |
| **Misconceptions addressed**  | ● Atoms cannot be changed from one element to another  
|                               | ● Once a material is radioactive, it is radioactive forever |
Half-life

Original Lesson Plan

In the original lesson plan, students simulated half-life reaction of the element “Pennium”. Students would shake up 100 pennies in a jar, every minute students would pause and record how many pennies decayed (Face down). Students’ would then remove the pennies that decayed and redid the steps with the remaining pennies until there weren’t any left. This activity was followed by a graph that students would create and a discussion about what was observed.

This hands-on activity is a great way to introduce students to half-life, but it was not enough for students to fully understand what is happening at a molecular level. Students enjoyed the activity but struggled understanding that “half” the amount of the radioisotope decays during each half-life. A simulation could supplement this activity by providing students the opportunity to set up a half-life scenario and observe the decay over a time span.

Supplemental simulation activity and Rationale

In this simulation, students can choose as many radioisotopes for their scenario. The simulation will then demonstrate what happens as time progresses. A visual representation for C-14 is a great example to do with students. In image A, it can be seen that only half of radioisotopes remaining decay every time.

![Image A](image.png)

The simulation also shows that the decayed isotope turned into a new element and a neutron is released (circled in blue in Image A)

This activity helps students by:
- Being able to visualize the decay of the chosen radioisotope.
- Providing the opportunity for students to observe that the nuclei is not disappearing, instead that it is breaking down to form new products.
- Providing a visual representation of how much is decaying in every half-life.
Studies have shown the importance of using simulations. It helps clarify rigorous concepts by helping students “see” concepts learned (Lui, M., & Slotta, D., 2012, Page 76). Another benefit is that students outperform academically when learning content from simulations (Lui, M., & Slotta, D., 2012, Page 76).

**Students outcome:**

**Students will:**

- *Create a narrative for the fission reaction.*
- *Rationalize why the reaction is sustainable from what was observed in the simulation.*

<table>
<thead>
<tr>
<th>Title:</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYS Chemistry Standard:</td>
<td>Stability of isotopes is based on the ratio of neutrons and protons in its nucleus. Although most nuclei are stable, some are unstable and spontaneously decay, emitting radiation. (3.1o) Each radioactive isotope has a specific mode and rate of decay (half-life). (4.4a)</td>
</tr>
<tr>
<td>Supplies and Resource</td>
<td>Simulation: <a href="https://archive.cnx.org/specials/f0a27b96-f5c8-11e5-a22c-73f8c149bebfbeta-decay/#sim-multiple-atoms">https://archive.cnx.org/specials/f0a27b96-f5c8-11e5-a22c-73f8c149bebfbeta-decay/#sim-multiple-atoms</a></td>
</tr>
<tr>
<td>Key Questions</td>
<td>How do radioactive isotopes decay over time?</td>
</tr>
</tbody>
</table>
| Summary of Activity: | In this activity, students will use a simulation to observe half-life reaction of Hydrogen-3 and Carbon-14. Students will be instructed to do the following: 
  - Choose a radioactive isotope to observe. Insert at least 4 to 10 isotopes. **Make sure you pause the simulation before inserting the radioisotopes.**
  - Press play and observe what happens as the time lapse reaches the first half life.
    - How many radioisotopes decayed in your first half life? 
    - Write a fraction that would represent the amount of your radioisotope remaining.
    - Did the isotopes that decayed in the first half life all decayed at once?
    - Create an explanation of what half-life is, justify your response with evidence from the simulation.
    - After each half-life observe what is being created.
    - What was produced? Where there any particles emitted? |
| Observable outcomes: | ➔ Students should identify that radioisotopes don’t disappear, instead they decay by breaking down the nucleus into new stable products. ➔ Students should understand that at each half life, half of the radioisotopes have decayed. |
| Misconceptions addressed | o Atoms cannot be changed from one element to another 
  o Radioisotopes change right at the half life. |
Unit - The Periodic Table

Properties of elements
⇒ Original lesson plan

In the original lesson plan, students explored the different properties of elements by either watching a video or using text. Students would gather the properties and organize them in a chart. This was followed by students completing a hands-on lab, where students explored samples of elements. The lesson is great, but it has a few downsides. One weakness of this lesson is that students are not able to experimentally explore a big variety of elements. Another weakness is that students are not able to study multiple physical properties of the elements in lab.

⇒ Supplemental learning activity and Rationale

A study discusses the benefits of using simulations to supplement hands on labs (Olympiou, G., & Zacharia, Z. C., 2011, page 25). This will benefit students by providing students the opportunity to explore past the limitation of the lab. Studies have also discussed how simulation teach students scientific inquiry and the process of scientific investigation (Peffer et al., 2015, page 10). A simulation by Glencoe help students explore flame color, melting point, boiling point, melting point and density for 10 unknown samples (Figure 14 and 15). Students would then try to match up what they have observed with the known properties of given elements. This simulation ideal to help students practice identifying unknown elements from the given properties through the process of experimentation.
**Students outcome:**

**Students will:**

- Investigate the physical properties of elements and identify samples of unknown elements from data of physical properties found in virtual experimentation.

<table>
<thead>
<tr>
<th>Title:</th>
<th>Physical properties of elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYS Chemistry Standard:</td>
<td>3.1w Elements can be differentiated by physical properties. Physical properties of sub stances, such as density, conductivity, malleability, solubility, and hardness, differ among elements.</td>
</tr>
<tr>
<td>Key Questions:</td>
<td>What elemental property trends can be found on the periodic table?</td>
</tr>
<tr>
<td>Summary of Activity:</td>
<td>In this activity, students will use a simulation to test the properties of different unknowns and use results to identify its identity.</td>
</tr>
<tr>
<td></td>
<td>Students will watch a video that discusses how scientist test unknown substance in order to identify them.</td>
</tr>
<tr>
<td></td>
<td>Students will test each unknown and write down their results from each test.</td>
</tr>
<tr>
<td></td>
<td>Students will then identify the unknown by clicking on the element they believe it is.</td>
</tr>
<tr>
<td></td>
<td>The simulation will let the students know if it is correct.</td>
</tr>
<tr>
<td></td>
<td>For additional support, students can use the data table for the known elements to compare with results.</td>
</tr>
<tr>
<td></td>
<td>Students can share out experience through class discussion</td>
</tr>
<tr>
<td></td>
<td>Possible discussion questions:</td>
</tr>
<tr>
<td></td>
<td>- How did this activity simulate what scientist do in the field?</td>
</tr>
<tr>
<td></td>
<td>- Thinking past this simulation, what chemical properties do you believe you can test in order to identify an unknown element?</td>
</tr>
</tbody>
</table>

**Observable outcomes:**

- Students will identify the unknown elements from data collected through virtual experimentation of physical properties.
- Students will justify the identity of unknowns by explaining supportive data from virtual lab.
Atomic radii trends across a period and down a group

⇒ Original Lesson Plan

In the original lesson plan, students watched a video about the atomic trends. This video was used to introduce atomic trends because it helped students visualize some of the trends in the periodic table. The video was followed by students using a table that lists measurements for atomic radii in order to discover the trends as you go across a period or down a group.

This activity was used because students both watch a video (ideal for visual learners) and used data from the reference table to recognize trends. Many times, I had to draw the elements going down a group for students to visually see the trend. This can become time consuming and not necessarily effective for students learning.

⇒ Supplemental simulation activity and Rationale

To enhance the above lesson, the simulation by “teachchemistry” can be integrated in a lesson to motivate or help students to explore some of the trend found on the periodic table. This simulation helps you to compare elements sided by side by clicking them. Students can now compare the atomic radii of chosen elements to discover a trend. Ideally, this simulation is intended to create an inquiry-based activity where students discover atomic trends through investigation and analyzing data. Not only does this simulation provides opportunity for meaningful learning, it provides student with practice of analytical and investigative skills learned in science (Schmidt et al., 2018, page 34).

This activity helps students by:

- Working together, applying critical thinking, to analyze and identify atomic trends (Altun, S., 2015, page 453).
- Providing the opportunity students to partake in scientific investigation in the classroom (Peffer et al., 2015, page 10). Students can visually see the decrease of atomic radius as you go across a period.

Students outcome:

Students will:

- Explore elements and their physical properties.
- Create and justify trends for atomic radii for elements in the periodic table.
<table>
<thead>
<tr>
<th>Title:</th>
<th>Periodic Trends: Atomic radii</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYS Chemistry Standard:</td>
<td>3.1aa The succession of elements within the same group demonstrates characteristic trends: differences in atomic radius, ionic radius, electronegativity, first ionization energy, metallic/nonmetallic properties.</td>
</tr>
<tr>
<td>Key Questions</td>
<td>What elemental property trends can be found on the periodic table?</td>
</tr>
</tbody>
</table>
| Summary of Activity: | In this activity, students will use a simulation to the trend of first ionization and atomic radii. Students will do the following.  
● Look at different elements on the periodic table and investigate the trends of atomic radii.  
● Guiding questions:  
  o Write the atomic radius for the following elements in the square cutouts provided:  
    Hydrogen Potassium Phosphorous Argon Iodine  
    Lithium Calcium Chlorine Fluorine  
    Sodium Scandium Sulfur Bromine  
  o Arrange them by period  
    • Discuss and record any trend observed when the elements are arranged by period. Justify your answers by discussing it in terms of atomic number, mass number or subatomic particle.  
  o Arrange elements by group  
    • Discuss and record any trends observed when the elements are arranged by groups. Justify your answers by discussing it in terms of atomic number, mass number or subatomic particle. |

** Observable outcomes:**  
⇒ *Students should identify that as you go down a group, the atomic radii increase. This is due to the increase in number of electrons.*  
⇒ *Students should understand that as you go across a period, the atomic radii decrease.*
Atomic radii of atom vs. ion

⇒ Original Lesson Plan

In the original lesson plan, students were asked to draw a picture of a sodium atom and a chlorine atom. Students learn that an atom becomes an ion as it lose or gain an electron in order to complete a full octet. Students are then asked to redraw magnesium and chlorine as ions.

This activity was used because students had prior knowledge of drawing atoms and it helped with drawing the ion. Students struggle to see that decreasing or increasing # of electrons affects the atomic radii by increasing or decreasing it.

⇒ Supplemental simulation activity

This simulation helps students compare the atomic radius of an atom and its ion. Students can remove or add electrons. The simulation will adjust the atomic radius and first ionization energy for the ion. This makes a great way for students to visually see the radius change as the number of electrons are added or removed.

<table>
<thead>
<tr>
<th>Sodium Protons</th>
<th>Na Protons</th>
<th>Sodium Protons</th>
<th>Na Protons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrons</td>
<td>11</td>
<td>Electrons</td>
<td>11</td>
</tr>
</tbody>
</table>

Figure 16 models representing atomic radius in simulation

Students outcome:

Students will:

- Rationalize what happens to the radius and first ionization energy as an atom becomes an ion.
<table>
<thead>
<tr>
<th><strong>Title:</strong></th>
<th>Radius: atom vs. Ion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NYS Chemistry Standard:</strong></td>
<td>3.1aaThe succession of elements within the same group demonstrates characteristic trends: differences in atomic radius, ionic radius, electronegativity, first ionization energy, metallic/nonmetallic properties.</td>
</tr>
<tr>
<td><strong>Key Questions:</strong></td>
<td>What elemental property trends can be found on the periodic table?</td>
</tr>
<tr>
<td><strong>Summary of Activity:</strong></td>
<td>In this activity, students will use a simulation to the trend of first ionization and atomic radii. Students will do the following.</td>
</tr>
<tr>
<td></td>
<td>● Look at different elements on the periodic table and investigate the trends of atomic radii.</td>
</tr>
<tr>
<td></td>
<td>● Guiding questions:</td>
</tr>
<tr>
<td></td>
<td>o Write the atomic radius for the following elements in the square cutouts provided: Hydrogen, Potassium, Phosphorous, Argon, Iodine, Lithium, Calcium, Chlorine, Fluorine, Sodium, Scandium, Sulfur, Bromine</td>
</tr>
<tr>
<td></td>
<td>o Arrange them by period</td>
</tr>
<tr>
<td></td>
<td>▪ Discuss and record any trend observed when the elements are arranged by period. Justify your answers by discussing it in terms of atomic number, mass number or subatomic particle.</td>
</tr>
<tr>
<td></td>
<td>o Arrange elements by group</td>
</tr>
<tr>
<td></td>
<td>▪ Discuss and record any trends observed when the elements are arranged by groups. Justify your answers by discussing it in terms of atomic number, mass number or subatomic particle.</td>
</tr>
<tr>
<td></td>
<td>● Students will repeat the above the above but instead will observe</td>
</tr>
<tr>
<td></td>
<td>o How many radioisotopes decayed in your first half-life?</td>
</tr>
<tr>
<td></td>
<td>o Write a fraction that would represent the amount of your radioisotope remaining.</td>
</tr>
<tr>
<td></td>
<td>o Did the isotopes that decayed in the first half life all decayed at once?</td>
</tr>
<tr>
<td></td>
<td>o Create an explanation of what half-life is, justify your response with evidence from the simulation.</td>
</tr>
<tr>
<td></td>
<td>o After each half-life observe what is being created.</td>
</tr>
<tr>
<td></td>
<td>o What was produced? Where there any particles emitted?</td>
</tr>
<tr>
<td><strong>Observable outcomes:</strong></td>
<td>Students should identify that as you go down a group, the atomic radii increase. This is due to the increase in number of electrons.</td>
</tr>
<tr>
<td></td>
<td>Students should understand that as you go across a period, the atomic radii decrease.</td>
</tr>
<tr>
<td><strong>Rationale:</strong></td>
<td>This activity helps students by:</td>
</tr>
<tr>
<td></td>
<td>● Being able to visually see the radius change in size as it goes down a group or across a period.</td>
</tr>
<tr>
<td></td>
<td>● Students will be able to visually see the decrease of atomic radius as you across a period.</td>
</tr>
<tr>
<td><strong>Misconcept addressed:</strong></td>
<td>The atomic radius increases as you go across a period.</td>
</tr>
</tbody>
</table>
First ionization energy

This activity can come before or after students learn about any of the trends found on the periodic table.

⇒ Original lesson plan

In the original lesson plan, student defined first ionization energy after watching a video. Students would then identify the trend in the periodic table by looking at the values in tables. Students would write down the first ionization of specific elements in the same group or row and then asked to explain the trend. The lesson was effective in showing students where to look when finding values for first ionization energy, but it lacked making this trend memorable. Some misconceptions about ionization can be addressed with the use of this simulation.

⇒ Supplemental simulation activity

The ionization simulation can help support the lesson by helping students view the atoms of different elements side by side for comparison (figure 17).

Figure 17 Ionization comparison

The simulation also gives an option to display ionization values on a graph (Figure 18). Using the simulations, students can investigate ionization trends by analyzing a graph or by comparing values and atomic drawings for elements.
The simulation addresses key misconceptions by providing students with a diagram to reference when investigating the trend. Students can visually observe that the more energy shells, the lower the ionization energy is.

This activity helps students by:

- Being able to visually see the ionization change as it goes down a group or across a period.
- Students will be able to analyze a graph for first ionization energy.

_Students outcome:_

_Students will:_

- _Create and justify trends for first ionization by using energy levels, graphs and first ionization values given._
<table>
<thead>
<tr>
<th>Title:</th>
<th>Periodic Trends: first ionization energy.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NYS Chemistry Standard:</strong></td>
<td>3.1aa The succession of elements within the same group demonstrates characteristic trends: differences in atomic radius, ionic radius, electronegativity, first ionization energy, metallic/nonmetallic properties.</td>
</tr>
<tr>
<td><strong>Key Questions</strong></td>
<td>What is the trend of first ionization energy for the elements in the periodic table?</td>
</tr>
</tbody>
</table>
| **Summary of Activity:** | In this activity, students will use a simulation to observe the trend of first ionization energy. Students will do the following.  
  ● Look at different elements on the periodic table and investigate the trends of first ionization energy.  
  ● Guiding questions:  
    ○ Compare the ionization energy of Boron and Gallium.  
    ○ Why do you think the values differ? What factors do you believe contribute to this difference in values?  
    ○ *Students should be guided to look at the atomic model of both elements, specifically the distance between the valence electrons and the nucleus. This will guide students to recognize that the closer the valence electrons are to the nucleus (less energy shells), the higher the first ionization energy is.*  
    ○ Write the first ionization for 5 elements in the same group and 5 elements in the same period.  
    ○ Arrange them by period  
      • Discuss and record any trend observed when the elements are arranged by period. Justify your answers by discussing it in terms of atomic number and energy shells.  
    ○ Arrange elements by group  
      • Discuss and record any trends observed when the elements are arranged by groups. Justify your answers by discussing it in terms of atomic number and/or energy shells.  

  **Observable outcomes:**  
  → *Students should identify that as you go across a period or up a group, first ionization energy increases. This is due to the decrease in atomic radii.*  
  → *Students should understand that a decrease in atomic radius means more energy is needed to remove an electron from the outermost shell.*  

<table>
<thead>
<tr>
<th>Misconceptions addressed</th>
</tr>
</thead>
</table>
| ● Low ionization energy means it’s hard to remove an electron.  
| ● Increase number of electrons means that ionization energy increases.  

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Unit- Bonding

Covalent bonds

This lesson is usually taught right before ionic bonds and after Lewis dot structures. In the original lesson, students are asked to draw the Lewis dot structure for Hydrogen and oxygen. Students are then asked to simulate a bond between them by drawing it into their notebooks. The concept of covalent bonds are introduced by asking students to find the electronegativity of both elements and discussing what kind of bonds are formed between these elements. Students are able to understand how to draw covalent bonds but failed to understand the intramolecular relationship between the elements that form the bonds. In order to remedy this, a simulation is suggested to provide a visually interactive opportunity for students to understand covalent bonds in a much deeper level. Another misunderstanding is that student believe that the valence electrons are being equally shared in covalent bonds. A remedy would be a simulation that can demonstrate the attraction forces between subatomic particles in a covalent bond.

⇒ Suggested simulation

An interactive simulation by pbs learning media is suggested to compliment the activity by providing an interactive nature and visual representation of covalent bonds. This simulation discusses and illustrates the intramolecular forces between the elements. Figure 19 gives a visual representation of the interaction between the nucleus of an element and the valence electron of the other element during covalent bonding. This reinforces the understanding that they are not equally sharing electrons, but neither can take away a valence electron from the other element. The simulation also demonstrates the potential energy changes as the bond is formed (figure 20). This gives an advancing understanding that will be help with a future lesson. This simulation also provides opportunity for guided inquiry that is interactive and provides opportunity for long term learning (Chao et al., 2015, page 29).

![Covalent Bonding Tutorial](image)

*Figure 19 demonstrate the attraction forces between the nucleus and the valence electrons*
Figure 20 uses graph to show the potential energy changes as the elements come closer.

This activity helps students by:
- Being able to visually see the interactive forces between the nucleus and valence electron of another element in covalent bonding.
- providing an interactive method of learning/reinforcing understanding of covalent bonding and providing opportunity for long term learning (Chao et al., 2015, page 29).

Students outcome:

Students will:
- Students will explore the interactive relationship between valence electrons and nucleus of elements in covalent bonds.
- Students will understand how energy plays a role in covalent bonding.
<table>
<thead>
<tr>
<th>Title:</th>
<th>Covalent bonds</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYS Chemistry Standard:</td>
<td>5.2a Chemical bonds are formed when valence electrons are:</td>
</tr>
<tr>
<td></td>
<td>• transferred from one atom to another (ionic)</td>
</tr>
<tr>
<td></td>
<td>• shared between atoms (covalent)</td>
</tr>
<tr>
<td></td>
<td>• mobile within a metal (metallic)</td>
</tr>
<tr>
<td>Key Questions</td>
<td>How does the relationship between nucleus and valence electrons play a role in covalent bonding?</td>
</tr>
<tr>
<td>Summary of Activity:</td>
<td>In this activity, students will use a simulation to observe the intramolecular relationships that occur in covalent bonds. After completing the simulation (up to step 35) students will answer the following questions in a small group discussion.</td>
</tr>
<tr>
<td></td>
<td>o Discussion questions</td>
</tr>
<tr>
<td></td>
<td>o In terms of nuclear structure, how can we tell a compound is covalent?</td>
</tr>
<tr>
<td></td>
<td>o How would you describe the sharing of valence electron between two elements in a covalent bond?</td>
</tr>
<tr>
<td></td>
<td>o How does energy play a role in covalent bonding?</td>
</tr>
<tr>
<td>Observable outcomes:</td>
<td>➔ Students should recognize that valence electrons are not being shared between elements, instead neither elements have enough of an attraction force to complete pull the valence electron away from the other element.</td>
</tr>
<tr>
<td></td>
<td>➔ Students will begin to understand how potential energy is affected in covalent bonding.</td>
</tr>
<tr>
<td>Misconceptions addressed:</td>
<td>Elements in covalent bonds are equally sharing valence electrons.</td>
</tr>
</tbody>
</table>
Polar and Non-polar Covalent bonds

This activity can come after learning about Lewis-dot structures.

⇒ Original lesson plan

In the original lesson, students covered how to calculate electronegativity. This was done on the board. Students then watch a video about electronegativity and covalent bonds. A story is told to help students remember covalent bonds. The analogy “sharing is caring” is used. A downside to this lesson is that students assume that there is always equal sharing. This is a common misconception seen with this lesson. In order to address this misconception, polarity in a water molecule is usually discussed. Students tend to assume that water is equally sharing electrons and therefore lead to a misunderstanding of partial charges. After drawing the water molecule on the board, the misconception was addressed by drawing the charge distribution. After this demonstration, it is found that some students forget about partial charges and dipole of water. Once students learn about polarity, students tend to always assume that water is non-polar. The lesson lacks a memorable activity that students can always refer to in order to remember polarity (Altun, S., 2015, page 453).

⇒ Supplemental simulation activity and Rationale

The simulation suggested will help students learn about covalent bonds through an inquiry activity. The pHET simulation gives options for students to explore bonds between different elements. It provides a visual of the molecule and the distribution of charge in the molecule.

Figure 21: Partial charges and Molecular dipole
In figure 21, students can view the partial charges for the elements in the molecule. The important part is how this simulation demonstrates the molecular dipole. This demonstrates to students that although it is a covalent bond, the electronegativity pull is not equal between the atoms. It helps strengthen the idea of partial charges and polarity of water. Using this simulation will also develop deepen students thinking by prompting students to expand and use vocabulary such as polarity and partial charges to describe a covalent bond in different molecules (Levy, D., 2012, page 703). This is important because students will go from saying “it is covalent” to a more complex answer discussing intramolecular forces in the molecules.

This activity helps students by:

Being able to visually compare the electronegativity and partial charges in different covalent molecules.

This provides opportunity for a more memorable activity for students, especially kinesthetic learners, due its manipulative nature (Rehmat, et.al., page 753).

Students can develop their scientific vocabulary by using words like polarity and partial charges to explain the sharing of electrons in covalent bond by using this simulation and their observations (Levy, D., 2012, page 703).

Students outcome:

Students will:

- Students will explore the partial charge distribution and molecular dipole in various covalent elements.
- Students will investigate the difference between polar and nonpolar covalent molecules.
- Increasing complexity of explanation of intramolecular forces between the elements in the molecule by using polarity and partial charges.
**Title:** Polar and Non-polar covalent bonds

**NYS Chemistry Standard:** 5.2k The electronegativity difference between two bonded atoms is used to assess the degree of polarity in the bond.

**Supplies and Resource:** Simulation: [https://phet.colorado.edu/en/simulation/legacy/molecule-polarity](https://phet.colorado.edu/en/simulation/legacy/molecule-polarity)

**Key Questions**

How are charges distributed in covalent bonds? How do we label a molecule polar or non-polar?

**Summary of Activity:**

In this activity, students will use a simulation to observe the charge distribution between molecules in a covalent bond. Students will do the following.

- Guiding questions:
  - Compare the electronegativity between the different bonds in a molecule.
  - Are the partial charges equal? If so, how does that contribute to the sharing of the electrons? (dipole movement)

- Students should be guided to look at the electronegativity distribution between two fluorine, two oxygens and two nitrogen. Students are then asked to observe the charge distribution in water.

- Group discussion:
  - How would you describe the charge distribution between $F \cdots F$, $O\cdots O$ and $H\cdots H$?
  - What is the electronegativity difference between the elements in the bonds above?
  - This is equal sharing is called non-polar.
  - How would you describe the charge distribution between water molecules? Nitrogen cyanide?
  - What is the electronegativity difference between the elements in the bonds above?
  - That difference in electronegativity is called Polar.

**Observable outcomes:**

Students should identify that there is an electronegativity difference in covalent bonds.

**Misconceptions addressed**

Electrons are shared equally in covalent bonds.
**Ionic bonding**

⇒ Original lesson

Students can complete this activity as an introduction to bonding or following covalent bonding.

In the original lesson, students completed a tiered lesson that introduces Ionic bonds and how to write equations for them. Students worked on worksheets that asked them to combine certain elements together to form ionic bonds. These worksheets are used in order for students to learn how to combine elements and understand the ratios of the elements in a compound (balanced charges).

⇒ Supplemental activity

This simulation can be used to introduce ionic bonding, reinforce understanding of ionic bonding or as a supplemental activity to help students struggling with the concept. This simulation is a scaffolded activity that revisits charges and interaction between subatomic particle before discussing ionic bonds. The simulation provides interactive simulation followed by and explanation of the interactions between sodium and chlorine. In figure 23, an example of the simulation demonstrates the visual aspect of the simulation. The simulation provides many opportunities for students to interact with the simulation in order to observe relationships in ionic bonds (figure 24). Studies have shown the struggles students have with understanding interactions with atoms and how simulations benefit enforce this understanding (Khan, S., 2011, page 221).

![Ionic Bonding Tutorial](image)

*Figure 23 Visual presentation of interaction of ions*
Students will create and justify trends for first ionization by using energy levels, graphs and first ionization values given.

### Summary of Activity:

In this activity, students will use a simulation to learn how ionic bonds are formed. Students will complete the simulation by:

1. Watching and understanding the interaction between different charges.
2. Manipulating a crystal structure of sodium chloride and understanding that there are ionic bonds between sodium and chlorine.
3. After watching the simulation about valence electrons, understanding that Chlorine is accepting an electron and sodium is giving it away.
4. Complete the question that has students find the ionic formula for the displayed crystal structure.

### Observable outcomes:

- Students will observe interactions in an ionic compound and be able to explain what ionic bonds are and how they are formed.
- Students will be able to complete the assessment question in the simulation that requires students to find the formula for the ionic compound by understanding and finding the ratios between the metals and non-metals involved in the compound.
**Balancing chemical equations**

⇒ Original lesson

Student began this lesson by balancing a recipe for an omelet. This example showed students that matter is conserved and that both sides of a reaction need to be balanced. This was followed by demonstrating how to balance an equation and then having students’ practice. Many times, I would draw “moles” of each substance in both the reactants and products side. This was done to demonstrate to students what was being balanced. Students have also been observed to incorrectly balance equation when diatomic atoms are involved. Students seem to still struggle with understanding exactly what is happening when something is being balanced and a visual would help clarify this.

⇒ Supplemental activity

A pHET simulation is a great program to use alongside with this lesson. This simulation helped students balance equations by manipulating how many moles are on each side of the reaction. As students manipulate the coefficient of substances, images of the moles appear to represent the amount of substance you have in the equation. This simulation provides opportunity for practice by adding a game for students to try balancing more challenging equations. In figure 25, the practice simulation provides an additional source of support for students to check if their equations are balanced with “balance scale”. This demonstrates to students if they have too many products or too many reactants. Studies have shown that students participate in meaningful learning when adding simulations that clearly show an outcome (Cunha, A. E., Saraiva, E., Santos, C. A., Dinis, F., & Lopes, J. B., 2014, page 83). This simulation provides students the opportunity to manipulate reactants/products and then observe if both sides are balance by looking at the virtual manipulatives displayed.

![Particle diagrams helps students see what they are balancing.](image-url)

*Figure 25 Visual presentation of moles in an equation.*
**Students outcome:**

**Students will:**

- Demonstrate understanding of conservation of matter by balancing chemical equations.

<table>
<thead>
<tr>
<th>Title</th>
<th>Balancing chemical equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYS Chemistry Standard:</td>
<td>3.3c A balanced chemical equation represents conservation of atoms. The coefficients in a balanced chemical equation can be used to determine mole ratios in the reaction.</td>
</tr>
<tr>
<td>Key Questions</td>
<td>How are do chemical equation demonstrate conservation of matter?</td>
</tr>
</tbody>
</table>
| Summary of Activity: | In this activity, students will use a simulation to practice how to balance equations:  
1. Apply what you have learned by balancing the 3 equations in the introduction.  
2. Manipulating the coefficient of substances and pay attention to the diagrams of moles being displayed.  
3. If you need a little help, select tools and add the scale to help with your balancing of equations.  
4. Once complete, challenge yourself by playing the game and select one of the 3 levels to complete.  

**Observable outcomes:**  
⇒ Students will balance equations by manipulating the coefficient of substances in the chemical formula.  
⇒ Students will observe and understand that matter must be conserved in chemical reaction by balancing equations. |
Unit: Physical nature of matter

States of matter
This lesson introduces students to the behavior of matter at different phases. Students usually begin with prior knowledge of the behavior of matter. In the original lesson plan, students were asked to draw matter at different conditions and discuss properties at the different phases.

Task II Using the resources above, complete the graphic organizer below.

<table>
<thead>
<tr>
<th>State of Matter → Properties ↓</th>
<th>SOLID</th>
<th>LIQUID</th>
<th>GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle Diagram (use H\textsubscript{2}O) as your example Hydrogen O Oxygen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative distance between particles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 26 Properties of different states of matter Chart

Students use prior knowledge and resources provided to fill in the chart (figure 26). It has been observed that students do pretty well in filling in this chart with minor misconceptions that need to be addressed. One misconception is that molecules do not move as a solid. Another misconception is that student believe that the transition between phases of matters happen suddenly. A simulation is proposed in order to help students visually see what is happening at a microscopic level.

⇒ Supplemental activity and Rationale
A simulation by pHET can be used to address misconceptions and to provide opportunity for deeper understanding of behavior of matter at a microscopic level. The pHET simulation is interactive software that lets students select different samples to heat up or cool down. A few benefits identified is that student can visually see movement of molecules at different phases of matter. Students will be able to rationalize kinetic energy of molecules as temperature increases/decreases.

Students outcome:
Students will:

- Justify how energy and molecular movement changes during phase change.
<table>
<thead>
<tr>
<th>Title:</th>
<th>States of matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYS Chemistry Standard:</td>
<td>4.2 Explain heat in terms of kinetic molecular theory. II. Explain phase change in terms of the changes in energy and intermolecular distances</td>
</tr>
<tr>
<td>Key Questions</td>
<td>How does molecular movement and energy explain phase change?</td>
</tr>
</tbody>
</table>
| Summary of Activity: | In this activity, students will use a simulation to learn how molecules interact during different phases of matter. 1. Choose any of the substances listed on the simulation. 2. Click on solid. In terms of energy and molecular movement, describe what you are observing. 3. Click on liquid and then on gas. How is molecular movement and energy change as temperature increases? Is most of the substance in liquid state before it becomes a gas?  

Observable outcomes:  
→ Students will observe interactions between molecules during different phases of matter.  
→ Students will be able to describe, in terms of energy and molecular movement, matter as is undergoes different phase changes. |
Classification of matter

⇒ Original lesson/activity

Students would begin by brainstorming what matter is and what are different forms of it. This warm up activity was followed by students filling out a classification of matter flow chart (figure 27). Students would then complete an activity that has them draw molecular drawings of pure substances and mixtures.

![Matter flow chart from original lesson](image)

Figure 27 Matter flow chart from original lesson

This lesson lacks a visual that helped students to distinguish or classify matter. When we discussed substances, students sometimes associated Air as a pure substance. This helped to identify many misconceptions that were not addressed in the lesson. A misconception that has been identified in my classroom is that students confuse substances that are uniform in color as “pure” substances. Another misconception identified is that student believe that dissolving solutes in solutions causes solutes to “disappear”.

⇒ Supplemental activity

A simulation could be useful to help students understand the different classifications of matter. Students can use this simulation by being able to visually distinguish between pure substances and mixtures. Simulations have demonstrated that students appreciate being able to research and “see” relationship being studied (Lui, M., & Slotta, D., 2012, Page 76). Simulations used for this lesson can help students visualize the difference between concept learned that otherwise could not be seen in the classroom. A simulation by legends of learning is the ideal simulation that can address misconceptions. The simulation begins by providing students the opportunity to identify the difference between elements and compounds. This is important for students to understand in order for them to understand the difference between mixtures and pure substances. In both figure 28 and 29, screen shots of the simulation demonstrate how students interact with the program to classify substances as elements or compounds followed by assessment questions to verify that students are learning the difference between the two.
Students observe the melting of ice (figure 30 and Figure 31) and investigate what is happening in a molecular level. The purpose is for students to understand that pure substances may undergo phase changes, but a new substance is not formed.

The simulation further goes into discussing heterogenous and homogenous mixtures. Figure 32 and figure 33 are activities were students are both creating these types of mixtures and observing the molecular make up that makes it heterogenous/homogenous.
Figure 32 Homogeneous mixture

Figure 33 Heterogenous mixture

Students outcome:

Students will:

- Differentiate between pure substances (elements, compounds) and mixtures (heterogenous and homogenous mixtures).
<table>
<thead>
<tr>
<th>Title: Classification of substances</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NYS Chemistry Standard:</strong></td>
</tr>
<tr>
<td>3.1q Matter is classified as a pure substance or as a mixture of substances.</td>
</tr>
<tr>
<td>3.1r A pure substance (element or compound) has a constant composition and constant properties throughout a given sample, and from sample to sample.</td>
</tr>
<tr>
<td>3.1s Mixtures are composed of two or more different substances that can be separated by physical means. When different substances are mixed together, a homogeneous or heterogeneous mixture is formed.</td>
</tr>
<tr>
<td><strong>Supplies and Resource:</strong> Simulation:</td>
</tr>
<tr>
<td><a href="https://games.legendsoflearning.com/games/WyJnYW11cyIsMTIwNl0=">https://games.legendsoflearning.com/games/WyJnYW11cyIsMTIwNl0=</a></td>
</tr>
<tr>
<td><strong>Key Questions:</strong> How do we distinguish between pure substances and mixtures?</td>
</tr>
<tr>
<td><strong>Summary of Activity:</strong> In this activity, students will use a simulation to classify different types of matter.</td>
</tr>
<tr>
<td>1. students will follow the lesson on the simulation and aim to receive 3 stars for each concept discussed.</td>
</tr>
<tr>
<td>Discussion after simulation:</td>
</tr>
<tr>
<td>➔ How can we determine a substance is a pure substance?</td>
</tr>
<tr>
<td>➔ How can we determine something is a mixture?</td>
</tr>
<tr>
<td>➔ What are examples of each?</td>
</tr>
<tr>
<td>➔ In terms of molecules and behavior, how can we differentiate between a pure substance and a mixture?</td>
</tr>
<tr>
<td>➔ What laboratory techniques can we use to separate substances in a heterogeneous mixture? Homogenous mixture?</td>
</tr>
<tr>
<td>Observable outcomes:</td>
</tr>
<tr>
<td>➔ Students will observe the difference between pure substances and mixtures.</td>
</tr>
<tr>
<td>➔ Students will be able to describe why salt water is not a pure substance using behavior of matter and atoms involved in the solution.</td>
</tr>
<tr>
<td>➔ students will be able to identify some separation methods from the simulation.</td>
</tr>
</tbody>
</table>
Heating curve

Original lesson/activity

Students were introduced to the heating curve by using a handout where students label different parts of the heating curve (Figure 15). This activity is done as a class. Students label the phases of matter and what is happening to kinetic energy and potential energy.

Figure 34 Heating curve diagram

A misconception that arises from this lesson is students’ inability to understand that during a phase change both solid and liquid or liquid ad gas exists in equilibrium. In other words, ice does not just turn into liquid within seconds, bonds are breaking in and turning ice into water. These misconceptions could be clarified with visuals. I have used images with explanations, but it does not provide opportunity for long term learning.

Supplemental activity and Rationale

A simulation by ck12 has been found to supplement this activity. This simulation provides multiple opportunities for students to observe the molecular behavior of atoms at different phases. This will give students a visual to always refer back to when discussing the cooling curve. Studies have shown that students understand kinetic molecular theory (movement of particles) by using simulations that provide opportunity students to see molecular movement at different temperatures (Plass, J. et al., 2012, page 401). Figure 35 and 36 show what is happening to molecular bonds during melting point and vaporization. Students can see that during this point of a phase change, temperature may not be changing but molecules are breaking bonds to turn into liquid or gas.

Figure 36 Melting point

Figure 35 Vaporization
**Students outcome:**

**Students will:**

- **Explain what happens to molecules of water at different stages of the heating curve by discussing temperature, molecular movement and kinetic energy.**

<table>
<thead>
<tr>
<th>Title:</th>
<th>Heating curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYS Chemistry Standard:</td>
<td>4.2 Explain heat in terms of kinetic molecular theory.</td>
</tr>
<tr>
<td>Key Questions</td>
<td>How can we describe kinetic energy and molecular movement in the heating curve?</td>
</tr>
<tr>
<td>Summary of Activity:</td>
<td>In this activity, students will use a simulation to describe what is happening to water molecules at different stages of the heating curve.</td>
</tr>
<tr>
<td></td>
<td>1. students will select to watch the simulation go from solid liquid or solid to gas.</td>
</tr>
<tr>
<td></td>
<td><strong>Discussion after simulation:</strong></td>
</tr>
<tr>
<td></td>
<td>→ How can we describe molecular movement below 0°C compared to molecular movement over 100°C?</td>
</tr>
<tr>
<td></td>
<td>→ How would you describe the molecular movement as temperature increases?</td>
</tr>
<tr>
<td></td>
<td>→ How would you describe a phase change using kinetic energy, temperature and molecular movement?</td>
</tr>
<tr>
<td></td>
<td>→ Describe the transition between solid to liquid, liquid to gas from observations from the simulation.</td>
</tr>
<tr>
<td></td>
<td><strong>Observable outcomes:</strong></td>
</tr>
<tr>
<td></td>
<td>→ Students will observe the difference in molecular movement of solids, liquids and gas.</td>
</tr>
<tr>
<td></td>
<td>→ Students will be able to use kinetic energy, molecular movement and temperature to describe different points of the heating curve.</td>
</tr>
</tbody>
</table>
Energy diagram

⇒Original lesson/activity
After students learn about the heating curve and chemical formulas, we begin to discuss energy diagram for a chemical equation. Students are demonstrating how to find if a reaction is exothermic or endothermic. We begin this lesson by labeling the energy diagram of the combustion of methane. This activity went well with students, but it lacked engagement.

Figure 37 Energy diagram

⇒Supplemental activity and Rationale
A simulation by ck-12 provides an example that helps students apply concept learns to something they have interacted with. This simulation provides the opportunity for students to make real-world connections to what is being learned. Students look at the diagrams of different chemical used in heating/cooling pads (figure 38). Students can observe the energy diagram and the absorbing/releasing of energy as the reaction takes place. Research has shown that using real world applications in a chemistry classroom helps students to learn the content being taught more meaningfully (Baynard, L., 2010, page 35). This gives teachers the chance to have more meaningful learning happening in the classroom.

Figure 38 Energy diagram
Students outcome:

Students will:

- Explain what happens to energy in a chemical reaction.

<table>
<thead>
<tr>
<th>Title:</th>
<th>Energy diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYS Chemistry Standard:</td>
<td>4.1b Chemical and physical changes can be exothermic or endothermic. 4.1c Energy released or absorbed during a chemical reaction can be represented by a potential energy diagram.</td>
</tr>
<tr>
<td>Key Questions</td>
<td>How can we describe what happens to energy in a chemical reaction?</td>
</tr>
<tr>
<td>Summary of Activity:</td>
<td>In this activity, students will use a simulation to describe what is happening to energy in different chemical reactions. 1. Students will investigate different chemical reaction in the simulation and answer the following questions. → Analyze each chemical equation in the simulation. Write down the equations and label as exothermic or endothermic. 2. After observing the different chemical reactions and the effects on temperature: → Which chemical reaction is ideal for a heating pad? → Which chemical reaction is ideal for a cooling pad? Observable outcomes: → Students will observe the difference amount of energy released/absorbed in different chemical reactions. → Students will be able to analyze what was observed and conclude with which chemical reactions would make an ideal for heating pad and cooling pad.</td>
</tr>
</tbody>
</table>
Stoichiometry

Introduction to solutions

Original lesson/activity

Students are introduced to solutions with an activity with iced tea. Students are asked to draw and describe iced tea that is unsaturated, saturated and super saturated. This was used in the original lesson to provide students with visuals to always refer back to when students are discussing solubility. This lesson is absolutely great, but I wanted an activity that can demonstrate solubility past iced tea! We do have a solubility lab, but the lab schedule sometimes does not align with lessons. Research has demonstrated that students appreciate being able to “see” relationship being studied (Lui, M., & Slotta, D., 2012, Page 76).

Let’s explore:

If a perfect mixture of ice tea with no excess mixture powder on the bottom of the cup is saturated, what would an unsaturated and supersaturated cup of iced tea look like? Draw your solutions in the cup below and explain what you think you would observe.

Saturated: __________________________

________________________

Super saturated: __________________________

________________________

Unsaturated: __________________________

________________________

Figure 39 Iced tea activity in current lesson plan

A misconception that arises from this lesson is when students fail to recall what happens in a saturated and super saturated solution. Using a simulation will improve students’ visualization of what happens to a solution that is super saturated.

Supplemental activity

A simulation from pHET gives students the ability to manipulate saturation of different solutions. In figure 40 and 41 shows visual representation of what an unsaturated and super saturated solution looks like. A great feature in this simulation is the option to show values like molarity, solute amount (moles) and solution volume.
Students outcome:

Students will:

- Explain the difference between solutions of different saturations.

<table>
<thead>
<tr>
<th>Title:</th>
<th>Solution saturation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYS Chemistry Standard:</td>
<td>3.1 xxviii use solubility curves to distinguish among saturated, supersaturated, and unsaturated solutions</td>
</tr>
</tbody>
</table>
| Supplies and Resource  | Simulation:  
https://phet.colorado.edu/sims/html/molarity/latest/molarity_en.html |
| Key Questions          | How can we describe the saturation of a solution? |
| Summary of Activity:   | In this activity, students will investigate different solutions and describe the saturation.  
1. Students will complete an activity that guides them to investigate different solutions. Students will describe the saturation for a given solution.  
   A. Describe the saturation for the following solutions, use the simulation to create these solutions as a guide for your response. Make sure to set 1 mole of solute and 1L solution for all examples.  
      1. A .1M solutions of cobalt(II)Nitrate  
      2. A .5 M of potassium dichromate  
      3. A .5 M of potassium permangate  
   B. Create your own solution!  
      Using the simulation, manipulate the Liters of solution and moles of solute to represent a saturated solution, unsaturated solution and super saturated solution. Write your values below and draw an image of your observations.  
Observable outcomes:  
→ Students will observe and explain the difference between different types of solutions.  
→ Students will be able to create unsaturated, supersaturated and saturated solutions using the simulation. |
Moles

⇒ Original lesson/activity

For this unit students learned about moles from a video and a guided problem done on the board. Students would practice these calculations by answering regents style problems. This lesson lacks engagement. Before doing this lesson, an activity about the moles of a cookie recipe was used (figure 42 and 43). This activity proved to add some engagement in the classroom, but students seem to feel become bored with the topic. Many students disliked math in my classes and topics like these seem very unengaging and difficult to understand its purpose. Ideally, an engaging activity that would help students to want to learn and practice stoichiometry problems would be needed for this lesson.

**COOKING CHEMISTRY - CHOCOLATE CHIP**

In this activity you will be converting a recipe from moles to standard cooking measurements and then using that recipe to bake some cookies at home!

Use the following molecular formulas to calculate grams of ingredients. NOTE: Most of these substances have extremely complex molecular formulas. I have greatly simplified your activity by listing a representative formula only.

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>GFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour</td>
<td>C_{6}H_{12}O_{6}</td>
<td>120</td>
</tr>
<tr>
<td>Lemon Juice</td>
<td>C_{6}H_{12}O_{6}</td>
<td>192</td>
</tr>
<tr>
<td>Margarine</td>
<td>C_{8}H_{14}O_{2}</td>
<td>516</td>
</tr>
<tr>
<td>Milk</td>
<td>C_{3}H_{10}O_{2}</td>
<td>148</td>
</tr>
<tr>
<td>Molasses</td>
<td>C_{15}H_{22}O_{11}</td>
<td>540</td>
</tr>
<tr>
<td>Salt</td>
<td>NaCl</td>
<td>59</td>
</tr>
<tr>
<td>Vanilla</td>
<td>C_{14}H_{22}O_{5}</td>
<td>572</td>
</tr>
<tr>
<td>Eggs</td>
<td>C_{6}H_{12}O_{6}N_{2}</td>
<td>100</td>
</tr>
</tbody>
</table>

**Unit Conversions**

Use the following conversions to get from grams to a standard cooking unit of measure.

1 teaspoon of baking soda = 2.84g
1 teaspoon of vanilla extract = 4.73g
1 large egg = 50g
1 cup flour = 141.95 g
1 teaspoon salt = 4.16 g
1 cup butter = 236.59 g
1 cup sugar = 198.73 g
1 cup brown sugar = 141.46 g
1 ounce chocolate chips = 28.35 g
1 tablespoon lemon juice = 14.20 g
1 teaspoon baking powder = 2.84 g
1 teaspoon of cinnamon = 2.84 g
1 teaspoon cream of tartar = 2.84 g

**Chocolate Chip Cookies**

Yield: 4 Dozen 2½ inch Cookies Ingredients:

| Brown sugar | 0.31 mol packed brown sugar | 0.624 mol eggs |
| Vanila      | 0.062 mol vanilla             | 2.82 mol Chocolate Chips |
| Flour       | 2.66 mol flour                | 0.0335 mol baking soda |
| Salt        | 0.030 mol salt                | 1.084 mol butter |
| Sugar       | 0.44 mol sugar                | (at room temp) |

**Want to try it at home?**

**Baking Instructions:**

Preheat oven to 375°F. Stir flour with baking soda and salt; set aside. In large mixer bowl, cream butter with sugar, brown sugar, eggs and vanilla. Gradually blend dry mixture into creamed mixture. Stir in Chocolate Chips. Drop tablespoon of dough per cookie onto greased cookie sheets. Bake at 375°F for 9 to 11 minutes or until golden brown.

*Figure 42 Cookie conversion activity*
Conversion Instructions

Begin by converting moles to grams for each ingredient and record the grams in the table below. Next, convert the number of grams to your final baking measurement; again, record the measurements in the table below. Complete all of your calculations on the “Cookie Calculations” sheet.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Grams</th>
<th>Baking Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baking soda</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown sugar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eggs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vanilla</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chocolate Chips</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 43 Cookie conversion activity

A misconception noticed from this activity is that students tend to place the incorrect conversion when going from grams to moles or moles to grams. Additional practice can remedy this issue. In the past, I provided worksheets with additional practice, students would become easily uninterested in this approach.

⇒Supplemental activity

In order to increase student engagement in this topic, a ck-12 simulation was found to be a fun and interactive practice approach for students. The ck-12 simulation takes you to a carnival (figure 44). In this setting, you can click different areas that lead to a conversion problem (Figure 45). After completing all problems, the simulation offers a higher level of rigor by giving students the opportunity to work on multi-step conversion problems. This helps students practice setting up conversion problems in an interactive setting and provides challenging questions to keep students engaged.

Figure 44 Carnival setting of simulation

Figure 45 Mole problem
Students outcome:

Students will:

- Set up conversion problems for different mole problems in the simulation.

<table>
<thead>
<tr>
<th>Title: Mole conversions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYS Chemistry Standard:</td>
</tr>
<tr>
<td>3.3 viii calculate the formula mass and gram-formula mass</td>
</tr>
<tr>
<td>ix determine the number of moles of a substance, given its mass</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Supplies and Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation:</td>
</tr>
<tr>
<td><a href="https://phet.colorado.edu/sims/html/molarity/latest/molarity_en.html">https://phet.colorado.edu/sims/html/molarity/latest/molarity_en.html</a></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Key Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do you covert between different variable in chemistry?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Summary of Activity:</th>
</tr>
</thead>
<tbody>
<tr>
<td>In this activity, students will practice converting between moles, liters, molecules and grams.</td>
</tr>
<tr>
<td>1. Students will complete an activity that guides them to investigate different scenarios and set up the conversion problem.</td>
</tr>
<tr>
<td>A. Complete the first set of practice problems in the carnival activity.</td>
</tr>
<tr>
<td>B. Challenge yourself!</td>
</tr>
<tr>
<td>Once you correctly complete all the problems, you will be prompted to create multi-step conversion problems. Complete this set for full credit.</td>
</tr>
<tr>
<td>Observable outcomes:</td>
</tr>
<tr>
<td>➔ Students will be able to correctly set up conversion problems for mole, liters and molecules.</td>
</tr>
<tr>
<td>➔ Students will be able to challenge themselves by completing multi-step problems for stoichiometry problems.</td>
</tr>
</tbody>
</table>
References


