Using Haptic Virtual Reality to Increase Learning Gains and Construct Knowledge of Unobservable Phenomena

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Using Haptic Virtual Reality to Increase Learning Gains and Construct Knowledge of Unobservable Phenomena

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Chapter One: Introduction to Project

Introduction

Over the past two decades, there has been an innovative shift towards new trends in education. There has also been an increased pressure on teachers to provide students with more accessible, hands-on and exploratory activities and lessons to supplement learning. With the gradual implementation of the Next Generation Science Standards, students will be expected to build upon their prior knowledge each year by making connections to their environment to become more scientifically literate. During a student’s high school career is when they begin to think about their future careers. This time period is crucial in defining their interests, career paths, competence and confidence in science. Teachers should be deftly aware of how fundamental one’s motivational beliefs can be in determining their talents in science and whether they want to continue with a career in the field of science (Velayutham et al., 2012, p. 1363).

To increase student motivation and engagement, teachers often turn to virtual reality. Virtual reality can deliver instruction to students in a visually stimulating manner that can allow them to interact with phenomena that is unobservable in nature. Virtual reality also decreases the need for lab equipment that may not be easily accessible. Computer graphics have enhanced auditory and visual information, however many times these simulations lack a sensory component. Therefore, the evolution of haptic feedback technology offers learners the ability to extend their interactions and communicate with their environment beyond purely auditory and visual means by providing realistic force feedback (Wiebe et al., 2009, p. 667).

In the past decade, the emergence of haptic virtual reality has encouraged students to construct knowledge through personal experiences that normally would not occur (Minogue & Borland, 2016, p. 188).
An important aspect of education is the construction of one’s own knowledge, which is often difficult when there is no opportunity to directly observe the concept in nature. Therefore, the use of haptic technology and haptic feedback in the classroom can allow students to extend their interactions and communicate with their environment beyond traditional measures. Haptic virtual reality gives students an individualized and unique experience that they can share with one another while surpassing the typical every day experiences. Compared to other subjects, there has been an increasingly low interest in science among children due to lack of motivation and inability to connect it to the real world. When students are learning in an environment that offers more possibilities compared to a traditional lab environment, they are able to surpass the typical every day experiences they have been learning and build upon their prior knowledge.

Huang, Rauch & Liaw (2010) suggested that a virtual reality environment is imperative for allowing learners to receive an individualized experience. Virtual reality gives students feedback in a haptic or sensory manner to indicate when they are performing a task correctly or incorrectly (1174). The utilization of simulations generated by a computer to enhance microworlds is an ideal method to increase active engagement in the classroom when learning complex scientific concepts. With the addition of haptics, which is tactile and kinesthetic feedback, the user’s ability to interact with the virtual environment is enhanced (Minogue & Jones, 2009, p. 1359).

The design of this thesis is to create and compile a large amount of haptic virtual reality labs that teachers can access. The program that will be used is called zSpace, which is a haptic virtual reality software that allows students to utilize polarized sensory glasses and a haptic enabled stylus to interact with a virtual world on a specialized computer and manipulate micro phenomena. These labs can be used to deliver instruction about concepts that students may not
have any prior connection to or to supplement and enhance their learning gains. Many scientific concepts are considered to be fundamental when understanding many other scientific concepts. The goal is to create labs that will allow students to create a personal connection to scientific ideas through an engaging manner. When students receive instruction through a unique manner, they often become more receptive to learning and can therefore retain information in a more sufficient manner because they are able to construct knowledge from their observations and surroundings (Patchen, T., & Cox-Petersen, A, 2008, p. 1008).

**Project Design**

This project is designed to be a compilation of ten haptic virtual reality labs using the software zSpace. The labs will follow the NYS Living Environment Standards as well as the Next Generation Science Standards for living environment as well as physical/general science topics for middle school students. The project will be a list of available laboratories along with their appropriate fit into the curriculum and a description of how they fit New York State curriculum standards for the appropriate discipline. Each laboratory in the compilation will include the following:

- zSpace Application used
- Title of laboratory activity
- Course(s) for laboratory
- Unit or Topic this lab coincides with
- Suggested time allotment for activity
- NYS and NGSS standards associated with the laboratory
• Introduction and Rationale for choosing this laboratory (provides unique instruction about a concept that is too small, allows students to manipulate objects they typically could not in nature, concept would normally require much longer time to teach in typical class setting, laboratory simulation would provide a better visual of concept compared to other methods of instruction, provides students with a unique experience and discovery about the topic, lab captures student interest of a typically uninteresting topic, allows for student collaboration more so than traditional labs, provides differentiation for lesson with diverse learners, provides students with a guided sense of touch feedback to assess their actions) as seen in research provided in the attached literature review

• Benefits of choosing the virtual/haptic laboratory over the physical laboratory or if it is going to be used to supplement a physical lab (the lab limits the need for materials that are unobtainable in a classroom, helps with visualization of the topic, virtual laboratory saves money, decreases the need for modifications for students with disabilities, allows students to experience something they cannot in nature, it will be used to preview/review a scientific concept that will be taught in class etc.) as seen in research provided in the attached literature review

• Recommendations for implementing in the classroom (whether the directions need to be clarified, does the lab have to be scaffolded, should a guided lab or worksheet be used, if students can work in groups, if it is teacher led, if students are self-teaching etc.)

• The zSpace lab worksheet the students will follow and write on throughout the lab. These labs will be accompanied by screenshots of the lab for teacher use and reference,
however it is suggested that the students receive the labs without the screenshots as they will be experiencing these images on their zSpace computers.

**Significance of Project**

The purpose of this compilation is to provide teachers and students with the opportunity to complete a laboratory activity in an environment that is different from the traditional settings. For the NYS Living Environment Curriculum, there is a mandated number of laboratory hours that the students must complete. Not only can these labs serve to pre-teach a lesson, teach a lesson or re-teach a lesson, but they can also count as contact lab time. The software zSpace was chosen because it is a new technology that has already grasped the attention of students and teachers. The software is still new, however when teachers create labs that use any of the zSpace programs, they can publish it for others to use. The goal is to create labs that adhere to the NYS Living Environment Standards as well as the NGSS standards to serve middle school and high school students in either biology or general science classes. It is also inevitable not that there will also be students with disabilities or language barriers in the classroom. These labs can serve to instruct these students and assist them to make personal connections with what they are learning in the science classroom. When students are engaged in new manners, it allows them to be more receptive to what they are learning and will hopefully allow them to construct their own knowledge and increase their learning gains.
Definition of Terms

- **Haptic**- mainly refers to usage of the hands and receptors on the skin when sensing touch. With haptic technology comes haptic feedback, a force feedback system that refers to zones where force of a haptic sense is perceived by receptors found in muscles and tendons. Haptic feedback can be tactile, involving the feedback of signals like pressure, strain and heat through the skin, or it can be force feedback which affects the zones where the force that is applied from the virtual environment to the user by pushing back (Ucar et al., 2016, p. 541).

- **Constructivism**- recognizes instruction that is learner centered and encourages teachers to guide knowledge instruction rather than transmit the information. Students will take an active role in a constructivist environment and will focus on cognitive strategies, hands-on experiences and reflections that will enhance their learning and development (Patchen & Cox-Petersen, 2008, p. 996).

- **Embodied Cognition**- places emphasis on the importance of prior experiences to emphasize thought, knowledge and connections to the physical world.
Chapter Two: Literature Review

Contemporary Trends in Science

Inquiry Learning

Inquiry based instruction is in the forefront of teaching methods to enhance learning and foster independence amongst students. Since the 1990s, researchers have questioned whether or not certain school context factors can affect the success of inquiry based teaching methods (Pea, 2012, p. 37). In this study, 91 seventh and eighth grade science teachers from a large Northeastern United States public school district were surveyed to determine which human and sociocultural factors affect their inquiry based instruction. The school consists of 170,000 students of White, Hispanic, African-American and Asian backgrounds (Pea, 2012, p. 37).

To collect quantitative data from the 91 teachers during this research, a Likert-style survey was used to gather information about the teacher’s demographics including years of science teaching experience, certification in the subject taught and semester credits in science (Pea, 2012, p. 37). Another Likert-style survey was used to determine which human and sociocultural factors are important to their effectiveness as science teachers as well as what they believe will be available to them during the next school year. To qualitatively collect data, three teachers were observed six to seven times and were interviewed before and after each observation (Pea, 2012, p. 38).

Based on the quantitative results, Pea (2012) states the teachers felt that student motivation is the most crucial enabling factor, whereas team planning and school policies is the most important sociocultural factor that impacts their effectiveness in inquiry teaching (p. 38). Most felt they would receive support from peers, administrators and mentors within the next year, which would increase their effectiveness. What the teacher’s felt would hinder their
effectiveness is student motivation, student autonomy and parent involvement (Pea, 2012, p. 39). Although 44 of the 91 teachers were new, there was no statistical significance among the environmental factors between the teachers with varying degrees of teaching experience (Pea, 2012, p. 39). Overall, the teachers deemed it important that school personnel and students work together to ensure that inquiry teaching is successful. Since this district receives a great amount of support from the school, the teachers are able to deliver effective instruction through inquiry based methods.

Based on the qualitative results, Pea (2012) found that the three teachers used as test subjects believed they had appropriate materials to teach through inquiry, received many opportunities for professional growth and had support from principals and colleagues within each grade level (p. 42). Although interactions with colleagues was evident on grade level, the teachers agreed there was not much collaboration and support across grade levels (Pea, 2012, 41). Due to lack of cross-grade collaboration, teachers would receive a mix of students that are both familiar and unfamiliar with inquiry learning, which can affect how effective inquiry activities are carried out in class. All three teachers also agreed that since student maturity can impact their abilities to teach, it is best that students should start inquiry based learning at an early age (Pea, 2012, p. 41). The results of this study shed light on the idea that an encouraging and supportive work environment with proper policies in place and motivated students will allow teachers to effectively carry out inquiry instruction.

Although there was no statistical significance among teacher responses to the surveys based on their years of teaching experience, there was no mention of the years of experience among the three teachers that were qualitatively observed. Observing a new teacher compared to a veteran teacher may deliver a variety of results that could impact the findings. Utilizing only
three teachers to collect qualitative data is a very small sample size and may not account for valid findings that could generalize the district as a whole (Pea, 2012, p. 42). Another weakness in this study was the fact that 65 percent of the middle school science teachers were White and female. This data is significantly lower than the national average regarding gender and ethnicity, which is 83 percent White and Female (Pea, 2012, p. 38). Additionally, 92 percent had a valid state teaching license, 74 percent were certified in the subject area to teach, 92 percent had six or more semesters of credit in science, 62 percent obtained a master’s degree and 70 percent had ten or less years of teaching experience. The teachers at this Northeastern United States district were much more qualified than the national population (Pea, 2012, p. 38). Since the majority of the nation does not consist of this teacher demographic with high qualifications, it does not serve as a typical standard to compare the rest of the nation to in regard to effectiveness in inquiry teaching. This data may be helpful to school with a similar student and teacher population that adheres to similar policies, however it may not be helpful to states that are different (Pea, 2012, p. 42). Lastly, since this research was completed on the middle school level, it was limited in its ability to expand the comparisons in the data and encourage research on the upper secondary level (Pea, 2012, 43).

It is evident that there is a great deal of support within each grade level at the middle school, therefore it is suggested that there is more effort placed in increasing support in collaboration across grade levels (Pea, 2012, p. 43). Since the teachers mutually felt that student maturity influences receptiveness to inquiry based instruction, teachers should begin to implement inquiry based instruction at the elementary level (Pea, 2012, p. 43). Since this district is an anomaly compared to many other schools in the nation, they should communicate their strategies to help other national districts establish similar policies and encourage collaboration
rather than isolation among teachers to support their instructional delivery on an inquiry based level (Pea, 2012, p. 43). Further suggestions could include discussions about how parents can be more supportive and place less stress on their children during their transition into middle school and high school. Positive parental involvement and ideas to increase supportive teacher-parent relationships could enhance the effectiveness of inquiry teaching. Another implication of the findings suggested that the surveyed teachers felt that a smaller class size is important to teach inquiry effectively, however it is something that is very unlikely to happen in future school years (Pea, 2012, p. 39). Efforts to reduce class size would be a beneficial change in the class populations to increase learning and student autonomy.

Inquiry teaching increases a student’s ability to not only learn scientific content, but become masters in doing science and understanding the tentativeness of scientific research. While it has been argued that both guided and open inquiry can efficiently develop scientific skills and critical thinking, this research elicits the hypothesis that students who experience open inquiry are more involved in the learning process and develop better dynamic inquiry skills compared to those exposed to guided inquiry (Sadeh & Zion, 2009, p. 1140).

The research followed fifty 11th and 12th grade high-school biology students that were followed throughout their two years of the inquiry learning process. Half of the students, consisting of 18 females and 7 males, were exposed to open inquiry throughout the two years. The other half of the students, 19 females and 6 males engaged in guided inquiry (Sadeh & Zion, 2009, p. 1140). All students were from four general high schools, had similar socio cultural backgrounds and had similar levels of academic achievement (Sadeh & Zion, 2009, p. 1142). Each group was exposed to similar levels of inquiry skill challenges and their success was compared based on whether or not they received open or guided inquiry instruction from the four
different teachers involved in this research. The data collected throughout the two year time span included interviews, student inquiry summary papers, student logbooks and reflections (Sadeh & Zion, 2009, p. 1140). Throughout this time frame, the teachers were interviewed about their inquiry teaching methods every three months to ensure consistency throughout the study (Sadeh & Zion, 2009, p. 1142).

If both groups demonstrated an equivalent performance when executing this inquiry assignment, the conclusion would be that guided inquiry may be sufficient enough for building inquiry skills in the classroom over open inquiry. Inquiry is deemed essential to the classroom learning environment as it inculcates scientific understanding on a deeper level by allowing students to comprehend the tentative nature of science, analyze how and why scientists conduct their work using specific methods, identify patterns and consider alternative explanations for phenomena (Sadeh & Zion, 2009, p. 1155). The students that engaged in open inquiry were able to execute these tasks on a higher level than those engaged in guided inquiry. They were able to understand that inquiry is not an established path and modify their methods as unexpected results arose (Sadeh & Zion, 2009, p. 1155). While there was no significant difference between the groups in expressing their points of view during the research, open inquiry students were more likely to express disappointment and surprise throughout their project compared to the guided inquiry students. Demonstrating these emotions showed that open inquiry students are able to react to change and express anticipation (Sadeh & Zion, 2009, p. 1156).

Both open and guided inquiry groups had high levels of understanding the learning process as a whole, were able to explain the importance of their process and methodology and invest time into planning their project. Both groups were able to successfully utilize inquiry components correctly and supply examples for their evidence (Sadeh & Zion, 2009, p. 1153).
The guided inquiry group lacked skills in devising solutions, using a larger vocabulary, constructing better explanations for their results and decreasing their dependence on their teacher (Sadeh & Zion, 2009, p. 1154).

Interviewing the students was a major part of the data collection. Research has shown that the interviewer can affect the answers of the interviewee. Although the interviewer took notes during interviews rather than recordings to develop a sense of trust, some students were naturally reluctant to express their true feelings about the project since their answers could directly and indirectly affect their teacher’s evaluations (Sadeh & Zion, 2009, p. 1143). This could cause the data to be skewed depending on the student’s relationship with their teacher as well as their degree of hesitancy toward the interviewer. Another weakness in this study is small sample size. Not only was this study limited to a certain number of classes, students and teachers, but the number of females in the study significantly outweighed the number of males. This study may not be able to serve as a sufficient sample of the entire Israeli high-school student population (Sadeh & Zion, 2009, p. 1156).

Another major component of qualitatively collecting data was gathering student reflections from both inquiry groups. The only time reflections were gathered was at the end of the project, which resulted in poor and unfocused reflections offered by both groups. In the future, it is suggested that reflections are collected consistently throughout the project to increase the quality of the activity (Sadeh & Zion, 2009, p. 1156). It is also suggested that in order for teachers to increase their awareness of the elements of inquiry teaching, they should be offered the hands on experience of inquiry learning through professional development so they can decide how to properly apply either guided or open inquiry to their classrooms depending on the environment (Sadeh & Zion, 2009, p. 1157).
The achievement gap between Caucasian students and African-American and Hispanic students has always been large. Although Caucasian students typically outperform most students of other backgrounds, all groups have not fully reached the desired rates of proficiency (Marshall & Alston, 2014, p. 807). This goal of this study was to determine if inquiry instruction, specifically the Next Generation Science Standards (NGSS), could narrow this achievement gap by raising the performance expectations for what all science students should be doing in their K-12 classes. (Marshall & Alston, 2014, p. 808). The goal is to utilize the NGSS assessments to challenge the students on higher levels compared to the previous standardized tests that tested mostly lower levels of thinking (Marshall & Alston, 2014, p. 808). There are many ways in which students can be triggered to engage in higher level thinking, however inquiry-based instruction is a way to begin encouraging students to think at higher levels, develop a deeper understanding of a smaller breadth of content and engage in classroom discourse (Marshall & Alston, 2014, p. 809).

This study was conducted over a five year time period and analyzed a professional development project called Inquiry in Motion Institute. The subjects included 74 middle school teachers and 9,981 middle school students from 11 different schools in five different school districts (Marshall & Alston, 2014, p. 811). The main research questions asked during this five year study included “a) Do student proficiency levels increase for those engaged in effective inquiry-based instruction? (b) Do classrooms that utilize inquiry-based instruction demonstrate a narrowing of the achievement gap for minority students? (c) Do proficiency rates for both males and females increase in classrooms where teachers utilize inquiry-based instruction?” (Marshall & Alston, 2014, p. 810). Mainly, this study wanted to increase student achievement and narrow the achievement gap among students. Student achievement and proficiency was measured
throughout this study using The Measure of Academic Progress (MAP) science test, which adjusts the questions based on student success throughout the exam. Since the MAP test is aligned with science standards, its predictions for state assessments are reliable. The test also tests all science domains, which shows a combination of growth and retention in the domains the students may not have learned yet from their teachers (Marshall & Alston, 2014, p. 812).

When the student rates of proficiency were compared between the control group of teachers not participating in the NGSS inquiry instruction versus the teachers that were, it was evident that growth as well as an increase in MAP scores had occurred. Therefore, inquiry instruction can cause an increase in learning scientific practices, skills and concepts. Since NGSS calls for teachers to teach scientific skills side by side with content, those students involved in the inquiry process were able to experience phenomena they may not have experienced before, model ideas, plan investigations, test ideas, communicate results with peers and analyze their data to anticipate further investigation (Marshall & Alston, 2014, p. 818). Despite the fact that closing the achievement gap is a broad idea, this study was able to more narrowly demonstrate that all groups increased proficiency throughout the five year period and that the students exposed to inquiry far surpassed those that did not receive exposure. This demonstrates a reliable decrease in the size of the achievement gap (Marshall & Alston, 2014, p. 818).

One limitation of this study is the fact that it was only performed at the middle school level. Expanding this to reach more upper level grades can give a more holistic understanding of how the effect of guided inquiry can enhance student achievement and continue to narrow the achievement gap. Also, much of the inquiry studied during this professional development intervention involved math and science classrooms. This is not a reliable reference of inquiry outcomes for all teachers, subjects and students (Marshall & Alston, 2014, p. 818).
In an effort to stray away from classic lecture based learning, inquiry teaching strategies have been implemented to engage the students and explore their understanding in ways that allow them to encounter various experience. Although this specific professional development project demonstrated that students can move up in their proficiency levels, teachers need to be willing to accept these new instructional methods. Without the support of teachers and proper policies enforced in the district, teachers may continue to carry out instruction using traditional methods, allowing for no growth in their students proficiency. Inquiry learning alone is not the sole factor that determines how proficient a student can become. Other factors such as school climate, individual beliefs, student motivation and socioeconomic status should be studied as they could either hinder or enhance a student’s performance during inquiry learning (Marshall & Alston, 2014, p. 819). Although all teachers possessed similar years of experience, it is suggested that teachers receive proper training to create guided inquiry lessons and learn how to implement them in ways that are effective to feel as comfortable as possible. This will equalize the inquiry experience among teachers and decrease the likelihood of their inquiry teaching abilities to reflect any drastic changes in the student proficiency outcomes.

**Gender in Science Classrooms**

Within the last decade, the implementation of single-sex science classrooms has increased across the United States. In this study, data is collected to determine whether or not these single-sex science classrooms influence an adolescent’s attitude towards science in a more positive manner compared to coeducational science classrooms. Although the gap between girls’ and boys’ scientific performance has decreased, there is still a large underrepresentation of women in the fields of science and technology degrees and careers (Simpson, Che & Bridges, 2016, p. 1407). In 2009, 2.5 million females and 6.7 million males received a STEM degree. A
main postulation of this underrepresentation of women is the individual self-competence they possess (Simpson et al., 2016, p. 1408). Since one’s ambitions and career goals are developed during the early stages of education, a student’s self-concept can heavily impact how they feel they will succeed in science.

Various studies have demonstrated that females in single-sex class settings have a higher self-concept compared to females in coeducation settings (Simpson et al., 2016, p. 1409). To determine if single-sex or coeducation science class settings can affect male and female student’s self-concept, 204 students from one middle school in the southeast United States were studied. Of the 204 students, 58 were males in a coeducational science class, 52 were females in a single-sex science class and 34 were females enrolled in a coeducational science class. Additionally, 86% were White, 7% were African-American, 5% were Hispanic, 1% were Asian and less than 1% were American Indian (Simpson et al., 2016, p. 1410). To measure the student’s self-concept in science, the Fennema-Sherman Mathematics Attitude Scales were used, which included 47 statements involving mathematics but rephrased the questions to relate to science (Simpson et al., 2016, p. 1410). To answer each question, a Likert scale was used to determine if the students strongly disagreed, disagreed, were not sure, agreed or strongly agreed with each statement (Simpson et al., 2016, p. 1411). The questions the students answered measured if they thought science was more suited for males, females or both, if their confidence affects their performance in science, how useful they felt science was to their future and how they felt their teacher perceived them as a science learner (Simpson et al., 2016, p. 1411).

The findings of the scale constructs indicated that both girls and boys were less likely to perceive science as a field more suited for males (Simpson et al., 2016, p. 1414). This contradicts previous notions that science is perceived to be male dominated. As for class type, the students in
a single-sex science class possessed a drastically higher confidence level in their scientific abilities compared to those in the coeducational science classes (Simpson et al., 2016, p. 1414). Based on these findings of higher confidence levels in single-sex classrooms, it is possible that this type of environment offers a more comfortable and self-assured learning environment for students. Although there is a positive correlation between same sex environments and learning, there are many factors such as prior student achievement, intrinsic and extrinsic motivation, instructional delivery and teacher reinforcement that can affect self-concept as well (Simpson et al., 2016, p. 1414).

In addition to the main questions that sought out to determine whether or not a single-sex or coeducational science class can increase the confidence level of male and female students, Simpson et al. (2016) compared academic self-concept between females in both types of class environments as well as males in both types of environments. In regards to females, those in the single-sex science class possessed a higher self-confidence to learn and perform scientific skills than those in the coeducational science setting. When comparing males, there was no significant difference in academic self-concept between the two class settings (Simpson et al., 2016, p. 1415). Therefore, there is a strong correlation between single-sex and coeducational class settings having a varying impact on female students as opposed to male students.

This study was carried out in a region of the United States that was predominantly white and only involved middle school students. As a sample, this does not give a completely accurate depiction of most school environments in the United States. Expanding this study to either involve high school students or follow elementary school students into their high school career could be an effective way to determine whether or not single-sex or coeducation class settings an impact their confidence in science. Due to this limitation involving only middle school students,
we cannot consider these results to generalize all school populations (Simpson et al., 2016, p. 1415). This study was also carried out during a small moment in time during these students’ middle school careers. Therefore, it is difficult to determine if their survey responses were based on a current class experience as opposed to their overall perceptions of science (Simpson et al., 2016, p. 1415). Another weakness in this study is that the school that this study was conducted in allows the students to choose if they would like to be enrolled in a single-sex or coeducation class, which could decrease the objectivity of the results since students have the ability to choose their learning environment (Simpson et al., 2016, p. 1410). To support the notion of girls feeling more confident in single-sex classrooms, further research could be conducted to address certain reasons why they may feel this greater sense of confidence. Also, the idea that a higher level of confidence directly connects females to a STEM related career can be explored through further research (Simpson et al., 2016, p. 1416).

For many years, gender gap issues in science have persisted and are even more pervasive today. Presently, gender differences exist in the realm of student achievement, course selection in the field of science as well as a choice of a career path in science (Velayutham, Aldridge & Fraser, 2012, p. 1347). It is crucial that science teachers are aware of the role that gender may play in a student’s ability to be motivated and self-regulating in the classroom so the teacher can respond appropriately. Self-regulation is one of the keys to a student’s academic success as it represents the control that one has over their own learning to achieve a goal (Velayutham et al., 2012, p. 1348). In conjunction with self-regulation, goal orientation is important to predict the level of student motivation since it can explain their willingness to learn as well as their comprehension and mastery of tasks (Velayutham et al., 2012, p. 1349). Lastly, this study sought out to prove that students are more willing and able to learn if they believe that they are capable
of doing so. Having self-efficacy is one of the driving factors that allows students to utilize self-regulatory strategies, evaluate their own progress and spend appropriate amounts of effort towards task completion (Velayutham et al., 2012, p. 1351).

The self-perception of boys and girls continue to show that boys have a higher interest and ability in science. Since girls are more likely to conform to stereotypic gender roles, they have a lower self-perception of their scientific abilities, even when their performance is higher than their male classmates (Velayutham et al., 2012, p. 1351). Therefore, the methods in this study involved supporting the belief that a student’s motivational belief in science would positively influence their self-regulation. Additionally, gender would moderate the predicted relationship that this study will model (Velayutham et al., 2012, p. 1352). The study consisted of 1,360 students from five different public schools in Perth, Western Australia, which consisted of 719 boys and 641 girls from 78 eighth, ninth and tenth grade classes. This sample represents the lower level students of the secondary schools based on their socioeconomic backgrounds and science literacy levels. Student learning was assessed by utilizing the Students’ Adaptive Learning Engagement in Science (SALES) instrument, which identifies student motivation and self-regulation in learning science (Velayutham et al., 2012, p. 1352).

As a result, this study found that motivation constructs in the categories of learning goals, task value and self-efficacy were very influential predictors of a students’ self-regulation in science (Velayutham et al., 2012, p. 1361). By promoting a student’s self-regulation in learning science, the student can become a more successful student with high values of learning, task value and self-efficacy (Velayutham et al., 2012, p. 1361). As for gender, the most influential construct for both boys and girls is self-efficacy. Although literature in the past has been consistent with implementing self-efficacy in science on girls, this study has shown that it is
necessary for both girls and boys to develop self-efficacy to assist in their self-regulation (Velayutham et al., 2012, p. 1361). For teachers who anticipate to improve student self-regulation, they should carefully select the specific teaching strategies that will most likely enhance their student’s confidence, whether they are male or female. Teachers should be mindful of individualizing scientific tasks based on student gender and abilities and should “reduce efficacy-diminishing failures” (Velayutham et al., 2012, p. 1361). It is important that teachers set tangible and realistic goals for their students to increase their confidence level as well as ability to achieve and set goals.

In addition to setting realistic goals and enforcing self-efficacy, it is suggested that teachers should discourage competition, decrease criticism and offer students the availability of choice to have a more cooperative and safer classroom environment. Along with a supportive classroom environment, teachers should also encourage an interest in the science concepts that they are learning. Emphasis on the value of comprehending information as well consistently praising the students can help narrow the gap of thought that males have a higher science aptitude than girls (Velayutham et al., 2012, p. 1362). With self-regulation at the top of the list for a successful classroom environment, the results of this study suggest that in order to offer equal success for both girls and boys, boys need to classify a science task as something valuable to them. Contrastingly, girls will self-regulate themselves regardless of the value they place on a task (Velayutham et al., 2012, p. 1362). Therefore, teachers should ensure that their male students will deem the tasks valuable over their female students in order for all students to be able to initiate the task with the utmost self-regulation and efficacy. It is imperative that the importance of science is inculcated into the male students in order for them to possess motivation for the tasks at hand.
During a student’s high school career is when they begin to think about their future careers. This time period is crucial in defining their interests, career paths, competence and confidence in science. This study suggest that teachers should be deftly aware of how fundamental one’s motivational beliefs can be in determining their talents in science and whether or not they want to continue with a career in the field of science (Velayutham et al., 2012, p. 1363). In both Australia and internationally, highlighting the importance of academic progress in male students should be in equilibrium with preserving the development of female students in an effort to overcome the ever-present gender differences in a female’s selection of both science courses and career paths (Velayutham et al., 2012, p. 1264).

A majority of the reports from this study were self-reported, which could increase the amount of bias in the results. A more multi-method approach of collecting data, incorporating case studies, conducting classroom observations and holding comprehensive interviews with both students and teachers could present more valid results in understanding student’s motivational beliefs (Velayutham et al., 2012, p. 1364). Although this study analyzed data from students in eighth, ninth and tenth grade science classes, the study did not compare the grade-level differences to each other. This limited the research to studying students only within each grade and not across grade levels. This study can also be expanded to include the upper level secondary students in eleventh and twelfth grade to see which grades possess higher motivational and self-regulatory characteristics (Velayutham et al., 2012, p. 1364).

A common belief is that boys typically have a higher achievement in STEM compared to girls. However, a more supported belief suggests that it is not so much their ability that sets apart their achievement but rather their perception in having a career in science (Wood, Ellison, Lim & Periathisuvadi, 2011, p. 46). The underrepresentation of women in STEM related careers is
undeniable. Therefore, if a smaller gap exists between male and female achievement in secondary science, we will see more involvement of females in STEM related college placement and careers.

In an effort to encourage long-term college placements and careers in the field of science, the National Science Foundation (NSF) funded the Bringing Up Girls in Science (BUGS) program. This study followed 32 girls in grades 4 and 5 from an urban community in North Texas that participated in an afterschool environmental science program with an engaging curriculum and mentor support. At the time of this study’s completion, it had been eight years since the BUGS project ended and one year since the fourth and fifth grade participants have been out of high school and either in college or the work force (Wood et al., 2011, p. 46).

To implement effective classroom curriculum for females, hands-on relatable and influential experiences that represent females’ interest areas should be incorporated in the classroom. Additionally, female students should be provided with informational feedback, should be exposed to successful females in science and taught that their scientific abilities can be expanded upon (Wood et al., 2011, p. 47). In the early grades, females have a high interest in learning science. Therefore, it is important that teachers continue to engage them by taking their learning styles into account to prevent the widening of the gender gap as the later years of schooling progress (Wood et al., 2011, p. 48). To aid in conserving their interest, female students should be exposed to women in the careers of science over a long period of time to increase the confidence of girls in their desire to continue their education in the field of STEM. Involvement in a positive mentorship could influence the female student’s current and future self-concept (Wood et al., 2011, p. 49).
The BUGS study analyzed groups of female students receiving support and mentoring from an after school environmental program and compared them against a group of similar female students that did not receive any support. To determine if the BUGS program increased the academic achievement of fourth and fifth grade girls in science, a follow-up STEM semantics survey was conducted on fourteen former BUGS participants as well as the all-female contrast groups (Wood et al., 2011, p. 50). When comparing the results of the Iowa Test of Basic Skills-Science (ITBS-S) pre and post-test from the initial study, the BUGS participants made substantial gains in comparison to the contrast group. Although their career paths are unknown when the girls are in fourth and fifth grade, this served as an indication that these female students have an increased awareness, confidence and appreciation in the field of science (Wood et al., 2011, p. 53).

When the follow-up survey results were analyzed, the participants were grouped into the categories of BUGS participants, Science Majors, Non-Science Majors, STEM Professionals and BUGS contrasts (Wood et al., 2011, p. 53). Compared to the other groups, the non-science majors had considerably less positive perceptions of science. Although the BUGS participants had a significantly more positive perception than the non-science majors, there was no major difference in comparison to those in the science majors group and the STEM professionals group. In both the career and perceptions in science subscales of the survey, the science majors scored the highest, BUGS participants scoring the second highest, STEM professionals scoring next, followed by BUGS contrast group and non-science majors (Wood et al., 2011, p. 52). In one last survey, intent in a career of science was measured. Since STEM Professionals are already in a career of science, the other four groups were surveyed for this subscale. The results
indicated that science majors have the highest interest in science as a career, followed by the BUGS participants, non-science majors and the BUGS contrast group (Wood et al., 2011, p. 53).

Although the study followed students from elementary school into college and beyond, there are some limitations of this research. One major limitation is the size of the sample group of female participants. Not only was the sample size relatively small to conduct the initial study, but less than half of the original participants completed the follow-up study survey (Wood et al., 2011, p. 53). This can question the validity of generalizing the idea that girls in after school science programs will be positively influenced to continue on a path to pursue a career in science. In addition, it is difficult to tell whether or not female students are interested in science as a career choice due to their involvement in the BUGS program or the fact that they have had additional exposure to science. Since the BUGS program involved a fusion of mentorship, summer programs and after-school programs, it is also difficult to ascertain which of the BUGS programs elements was most effective in fostering an interest in science (Wood et al., 2011, p. 53). In future research, it would be more sufficient to isolate the different elements of the BUGS program and test the effects of each element separately to determine the most effective variable. To ensure that the surveys used in this study are effective in measuring an interest in science, the BUGS participants should continue to be followed into their careers. This can help establish whether or not the implementation of an earlier intervention is necessary to increase self-efficacy in female students and result in the selection of more science related careers (Wood et al., 2011, p. 54).

**Technology in the Classroom**

The integration of technology in the classroom environment has been a method used by many teachers to enhance the science curriculum. In this two-year study, 34 teachers from 14
states and 876 students in sixth through ninth grade participated to determine if a traditional or video game-based learning environment is preferred when learning science (Marino, Israel, Beecher & Basham, 2013, p. 667). Since 2011, there has been an increase of evidence surrounding the positive outcomes of utilizing video games in the classroom to promote critical thinking and increase scientific literacy. Although there are many benefits to utilizing video games in the classroom, this study expresses how easily these games can impede learning rather than enhance it due to their lack of clearly defined learning objectives (Marino et al., 2013, p. 667).

Marino et al. (2013) sought out to enhance previous literature on the utilization of video games by also tracking the differences in the students’ reading ability and disability status (p. 668). Their reading levels were measured through National Assessment of Educational Progress (NAEP) reports and their disability status was determined by their classification through the Individualized Education Program (IEP) (Marino et al., 2013, p. 668). The games You Make Me Sick! And Prisoner of Echo was chosen for this study because they were universally designed for all students. This helped to bridge the gap among the student participants to support all lines of cognitive processing such as text-to-speech, animated tutorials for visual aid and a virtual dictionary. The game also allowed teachers to track and monitor the progress of their students during game play (Marino et al., 2013, p. 669).

Using these specific student learner demographics as the independent variable of this study, Mario et al. (2013) investigates the students’ attitudes and behavior toward science, video games, reading and computers (p. 668). In order to collect quantitative data in this study, pre and post interviews and surveys were conducted and distributed to both students and teachers to gather their perceptions about using video games in the science classroom as well as students’
thoughts on science, the work of science and science as a career. A main focus during the student post interviews involved more narrow questions such as suggestions for improving the game, the effectiveness of the game and whether or not they felt the game enhanced their learning (Marino et al., 2013, p. 669).

One of the main findings Marino et al. (2013) discovered through this study was that prior to the video game intervention, the students without disabilities expressed that they would rather learn science through the use of video games and those with disabilities preferred traditional laboratory work (p. 672). However, nearly all students communicated that they agreed that video games would make science more fun in both the pre and post-intervention surveys. When asking the students questions involving their attitudes toward science, a greater majority of students with advanced reading levels stated that they believe they are good at science both before and after the intervention. Contrastingly, the students with lower reading scores increased their confidence about being good in science by 19.8% after the intervention was implemented (Marino et al., 2013, p. 673). These results demonstrated that although students with lower reading levels prefer to utilize traditional based lab methods, the implementation of video games that were universally designed to assist their needs increased their confidence in science as well as their comprehension.

Results from the post-intervention teacher interviews supported the notion that video games would enhance the comprehension and confidence of all students regardless of their reading abilities and disabilities. A common sentiment expressed by the teachers was that the students that typically struggled during traditional written lab reports were some of the most engaged students while playing the video games (Marino et al., 2013, p. 674). The teachers stated that the students with IEPs and low reading levels became video game experts, helped
their peers and collaborated with their classmates. The levels of collaboration and support among students were a positive outcome of the video game that many of the teachers did not anticipate. What the teachers felt to be an individualized activity became an activity that the students shared their thoughts and findings about with one another (Marino et al., 2013, p. 675). The accessibility and universal design of the video games effectively increased student engagement and increased comprehension of the skill and concept at hand according to the teachers and students involved in the study.

Although this study had a large sample size of students and teachers, it was conducted over a period of seven days in the classroom, which is a very short amount of time. Regardless of the short amount of time, many positive trends were reported after the intervention was implemented. Another weakness of this study was that the learner variability of students with IEPs was a very broad range. Addressing this in future studies would be helpful in further disaggregating the results for the pre and post intervention surveys and interviews (Marino et al., 2013, p. 677). Future research could include a focus on how to construct both traditional and digital learning environment for diverse learners and compare student performance in UDL based learning to more traditional learning environments (Marino et al., 2013, p. 677). To improve the outcomes in STEM education, the study could also extend its efforts to include those students that are English Language Learners to attract more people into the field of STEM (Marino et al., 2013, p. 677).

**Concept Maps**

Concept maps are used to graphically represent concepts and relationships in a way that is organized, hierarchical and linked in structure (Martinez, Perez, Suero & Pardo, 2013, p. 204). A concept map is most effective when relationships between and among ideas are noted and
issues of knowledge, knowledge structure and ideas are related in a similar way to how a learner’s brain operates (Martinez et al., 2013, p. 205). In this study, researchers posed the question “What is the difference in learning results from the use of concept maps to study a particular topic in an engineering course?” to evaluate if the amount of learning increases between groups that receive instruction through concept maps compared to those that do not (Martinez et al., 2013, p. 204).

To determine how powerful concept maps are in forcing active learning in a student, 114 junior and senior college students pursuing an engineering degree were divided into two groups. The control group consisted of 57 students that received instruction through classical teaching methods, which relied on texts and other traditional resources to explain content. The experimental group consisted of 57 students that received instruction using concept maps through a software-mapping program. Both groups were taught new high-level content and were instructed by the same teacher to restrict the learning differences to a single variable (Martinez et al., 2013, p. 208). To further control the experiment, the content the instructor chose to teach ensured that the students had little to no prior knowledge of the topic. This further limited the influence of their understanding on the final results of concept map exposure (Martinez et al., 2013, p. 208). To quantitatively measure the students’ knowledge gains, two post-tests of 100 dichotomous questions were used to demonstrate conceptual understanding. In addition, interviews were conducted upon the culmination of instruction to determine the level of student satisfaction of their understanding as well as their opinions on the concept map (Martinez et al., 2013, p. 209).

The construction of concept maps by the students themselves is claimed to be a collaborative way to construct knowledge on a concept. Working through the map and physically
building upon prior knowledge is a skill that is brought about through the utilization and creation of concept maps. Although this facilitates learning, concept maps that are constructed by expert teachers are a helpful tool that students can utilize to study concepts learned in class. This led the researchers in this study to allow for the expert teacher create the concept map and allow the students to collaboratively reconstruct the map as they see fit in regards to their personal understanding (Martinez et al., 2013, p. 208). As a result of this method, the increase of learning between the control group and the experimental group was greater than 19 percentage points (Martinez et al., 2013, p. 204). When students were interviewed regarding their thoughts on concept mapping, many believed that the collaboration with classmates was key in exchanging knowledge with one another and helped to build upon pre-existing knowledge. Students expressed that mapping helped identify key connections between concepts they already know with the new high-level material taught by their teacher (Martinez et al., 2013, p. 208).

Although this study was conducted with students of an Engineering course in their junior and senior years, there was enough data to support the substantial knowledge gains between the groups that received and did not receive instruction through concept mapping. However, this study does not generalize all populations of students as it involved a very homogeneous group of students that were in a similar class by choice, demonstrated similar levels of knowledge and were not classified to have any type of learning disability (Martinez et al., 2013, p. 205). Expanding this study to involve students in middle school and high school taking various science courses could offer a wider range of data. This study was also limited to students being taught by one teacher. Although this acted as an experimental control, it would be worthwhile to have a larger sample size of teachers to make a more valid conclusion that the use of concept maps is helpful for students despite the way that their teacher delivers instruction.
Lastly, the students received the concept map from the instructor. Utilizing concept maps created by students, or instructing students on how to skillfully create concept maps on their own could better validate that they are a crucial vehicle to build upon prior knowledge and actively link it to learned knowledge. This study presented some sentiments from students that demonstrated how effective they felt the concept maps were in helping them understand the material. However, this study did not state whether they preferred it to traditional teaching methods. Further questions on their perception of the instructional strategy may be helpful in determining various techniques on how to utilize it in the classroom.

**Writing to Learn and Drawing to Learn**

Scientific literacy has been a main priority in education for decades. Educators and researchers consistently search for new innovative ways to develop scientific literacy in students by engaging them in positive ways (Tomas & Ritchie, 2015, p. 42). Although the importance of literacy has grown, it has not progressed in a momentous fashion since teachers must spend most of their class time adhering to a curriculum that prepares the students for high profile assessments. Tomas and Ritchie (2015) expressed the importance of a scientifically literate student to be able to make informed social and personal decisions about scientific issues that go beyond what they must prepare for a state or national exam (p. 43). In order to increase scientific literacy in students, it is suggested that diverse, authentic and creative techniques are implemented to assess the students.

Educators are acknowledging the importance of writing to learn in science. In this study, the program BioStories is used as a way to differentiate writing to learn and to create a more centralized method of communication with peers and teachers (Tomas & Ritchie, 2015, p. 43). The main question addressed in this study is “To what extent is students’ scientific literacy
developed through the writing of Biostories?” and “How can students’ scientific literacy be evaluated effectively in this writing-to-learn science context?” (Tomas & Ritchie, 2015, p. 44). One of the main goals of science is to allow students to connect what they learn with the real world. Therefore, the central idea of this study was to have the students’ scientific literacy develop through communicating their understanding about biosecurity. (Tomas & Ritchie, 2015, p. 43).

The participants in this case study included a classroom of 26 students aged 13-14 years old, which was taught by their highly experienced regular classroom teacher. The class consisted of males and females and their progress of completing two unfinished Biostories was studied over a five-week period (Tomas & Ritchie, 2015, p. 44). This activity was embedded within a seven-week ecology unit in the curriculum, which avoided the problem of having to take away too much class time to be involved in this research. To make this case study more student centered, the teacher’s role was limited to explaining their task at hand, assisting students in their research when needed and reviewing their drafts (Tomas & Ritchie, 2015, p. 45). To collect quantitative data about the students’ progress, Tomas & Ritchie (2015) developed matrices with specific criteria that was numerically rated to assess how well the students accomplished the Biostories task requirements (p. 46). To collect qualitative data about the students’ understanding, 24 of the 26 student participants agreed to be interviewed and recorded two to six weeks after the culmination of the project. In conjunction with student interviews, classroom observations and reviews of the Biostories written by the students were utilized to further discussions in the interviews. The recordings of these interviews were analyzed to determine the understanding of biosecurity of each student (Tomas & Ritchie, 2015, p. 47).
A main result that was discovered towards the end of this study was the disparity between the students’ written work and their oral interviews and explanation of their findings. Many students were able to recall and articulate more concepts at a deeper level of understanding compared to their written work. Contrastingly, students that were able to offer thorough explanations in their written work expressed superficial or alternative concepts in their interviews (Tomas & Ritchie, 2015, p. 48). It is hypothesized that due to the open ended nature the writing assignment offered, students tended to stray from being systematic in their approach. This caused some students to have writing assignments that were less task oriented compared to their oral explanations. With this inconsistency between the written and spoken understanding of the students, Tomas & Ritchie (2015) presented their findings as an analysis of both the students’ literacy scores as well as their interview findings in an effort to comprehend student understanding and literacy development at a deeper level (p. 48). As a result of analyzing both written and oral explanations, the use of BioStories indicated an improvement in student literacy and a deeper conceptual understanding in 19 of the 24 students (Tomas & Ritchie, 2015, p. 53).

Due to the evident differences in the student responses in their written and oral explanations, some may question the validity of the conclusion stating that scientific literacy in students has increased (Tomas & Ritchie, 2015, p. 53). However, this revealed the importance of implementing multiple ways to assess students to paint a larger picture of their literacy development since one type of assessment cannot give a reasonable depiction of student achievement. To ensure a more thoughtful written assignment, it is suggested that students engage in a more reflective review upon the completion of their work through peer or self-assessments (Tomas & Ritchie, 2015, p. 53). Since the students do not typically include everything that they know in their writing, a sole evaluation of their writing would provide a
limited view of what they understand. This study was also conducted in classroom with a small sample size of students and a highly qualified teacher. Expanding this study to accommodate more test subjects and various teachers could depict a more general idea of how well BioStories can increase literacy in students. With the growing population of special education students and English language learners, it would be interesting to extend this case study to determine how a literacy program could either impede or assist in the learning and literacy of these types of students.

A general science class is a core requirement for many students in school. Although these courses are broader compared to other subject specific science classes, many students find these classes difficult due to the verbiage and abstract concepts that accompany the course. It is important that the instructors in a general science classroom are cognizant of the abilities of their students as their disabilities and language barriers can prevent them from critically thinking (Copeland Solas & Wilson, 2017, p. 144). A traditional method to ensure that the instructor is gaining proper insight into their students’ understanding is the utilization of formative assessments.

Typically, teachers use formative assessments to provide feedback that is summative, written, from a peer or even a self-assessment. Although these provide feedback that is more instantaneous based on the students’ learning, it can be time consuming for teachers and does not target the deeper levels of learning that the students need to reach (Copeland Solas & Wilson, 2017, p. 145). Each student possesses different cognitive models for understanding considering each student has different prior experiences. Therefore, it is essential that teachers utilize formative assessments that provide insight into the cognitive models of their students to determine how much is really learned and to focus on any misconceptions (Copeland Solas &
Wilson, 2017, p. 145). One way to accomplish this is drawing to learn science, which allows students to provide representations and models of what they are cognitively visualizing. This allows teachers to see the thinking and learning that is going on in their students’ minds and the drawing demonstrates a more practical understanding of the material (Copeland Solas & Wilson, 2017, p. 145).

To study the benefits of drawing to learn, 150 female students in a general science class acted as the participants and sketched scientific concepts for over two semesters. All students were Arabic English Language Learners and had a similar background knowledge in science (Copeland Solas & Wilson, 2017, p. 146). The students were taught lessons on air pollution, ozone depletion and photochemical smog and were asked to represent their understanding through drawings. Each student was asked to include the main idea as well as the relationships between the ideas learned in the topic to demonstrate their knowledge. Upon the completion of the drawings, 36 group sketches and 54 individual sketches were collected and graded based on a rubric (Copeland Solas & Wilson, 2017, p. 147).

Throughout the lesson, it was observed that the students were more engaged, collaborative and on task compared to when they complete more traditional tasks. When communicating with peers, students would utilize scientific terminology and check over their peers’ work to ensure all key points were identified. When the sketches were analyzed, it was clear that the students were able to sketch the information learned, which demonstrated that their prior misconceptions and knowledge gaps were due to previous learning experiences. It was also observed that more detail, sketches and ideas were more evident when the students worked collaboratively on a group sketch compared to individual sketches (Copeland Solas & Wilson, 2017, p. 148). When the teachers analyzed the drawings to give feedback to the students, a chart
was created that addressed the misconceptions, alternative conceptions and knowledge gaps about ozone depletion and photochemical smog. This is useful for the teachers when providing more comprehensive feedback to the class as a whole and can also guide how the material is taught for the next lesson (Copeland Solas & Wilson, 2017, p. 153).

A benefit of utilizing sketches allows students who are English Language Learners or have a lower achievement compared to their peers to reduce their cognitive load to demonstrate understanding. Sketching also allows students to express themselves creatively and uniquely which can often be suppressed when completing traditional assignments (Copeland Solas & Wilson, 2017, p. 158). By analyzing sketches, a teacher can almost trace the thought process of their students and determine where certain misconceptions arose and address them immediately. Although many students left out details or depicted some incorrect relationships, the sketches outlined their thinking in a way that multiple choice questions or open-ended assessment questions may not have (Copeland Solas & Wilson, 2017, p. 158).

Although this study had a relatively large sample size of 150 students, it was limited to females that were all Arabic English Language Learners. This does not generalize all populations and it would be worthwhile to include both males and females in this study. Expanding this study to include both upper and lower grade level students in both general education and inclusion settings could further disaggregate the data to see how beneficial sketching to learn is to different student populations. It would also be interesting to see how the knowledge gains of students who sketch their understanding differs from students that express their understanding through more traditional means such as an assessment.

It is suggested that this sketching technique begins in the lower grades in order to carry this skill into the upper grades. Utilizing sketches can be carried into all scientific subjects such
as biology, chemistry and physics. Many of the science classes are very diagram based, and if the students are able to produce sketches that depict their cognitive models their teachers will be able to better structure lessons towards the students’ understandings (Copeland Solas & Wilson, 2017, p. 158). It would be beneficial for teachers to also allow their English Language Learner students as well as their students with disabilities to utilize the sketching to learn technique more often to ensure that knowledge gains are happening frequently (Copeland Solas & Wilson, 2017, p. 158).

**Constructivism**

An increasing interest in reforming science education has been a topic of interest for many researchers. In many developed countries, science education has been constructed to accommodate and benefit the majority of students. In countries like South Africa, a universal science curriculum suitable for all students is not as feasible (Stears, 2009, p. 400). Upon the culmination of apartheid in South Africa in 1994, the goal was to shift Africa’s education from content-centered to a learner-centered curriculum. The goal was to connect science to the lives of black South Africans and increase their participation and achievement rates in science (Stears, 2009, p. 398). It is important for countries like South Africa with vast differences and diversity among their populations to offer a science curriculum that offers opportunities for students and allows for the development of problem solving, critical thinking and creative skills (Stears, 2009, p. 400).

To achieve a more culturally centered environment, this study sought out to frame a science curriculum that is informed by both social and critical constructivist principals and observe how learners respond to this type of curriculum (Stears, 2009, p. 401). Social constructivism involves the examination of the way learnings construct meaning in social contexts while critical constructivism assumes that knowledge is built by the learner and that the
goal of learning is to convert pre-existing knowledge to “emancipatory ends” (Stears, 2009, p. 405). It is crucial for learners to be able to find value in what they learn so they can apply their learned knowledge to their everyday lives. Therefore, it is important that teachers provide opportunities for learners to build upon their knowledge by using their individual experiences to influence the curriculum and the content learned. Stears (2009) states that if a social and constructivist approach is utilized in the classroom, teachers can use the science curriculum for social and personal development and aim to transform society in certain ways (p. 400). In order to do so, this study calls for teachers to acknowledge the social, historical and political issues in the community in which content is taught (Stears, 2009, p. 400).

This study involved a sixth-grade class of 45 students from a school in Gugulethu, South Africa in a community rich in poverty, alcoholism, abuse and HIV/AIDS. All the learners in this classroom were isiXhosa mother-tongue speakers and began to learn English at the start of this year (Stears, 2009, p. 401). A series of science lessons involving principles of social and critical constructivism was implemented in the classroom over a period of four days for three hours each day (Stears, 2009, p. 402). One aspect of a constructivist approach is that the learners collaborate and decide upon the topics they find most intriguing. Therefore, the learners decided to learn about fire. Once the topic was chosen, students were instructed to write about what they knew about fire or their own personal experiences with fire. When the students’ writing was analyzed, it was evident that there are clear social issues that need to be addressed as students frequently wrote about drunk adults leaving stoves, candles and other flames unattended causing a fire to break out (Stears, 2009, p. 402).

Stears (2009) stresses the importance of extending the knowledge of the students into a more conceptual domain (p. 403). To allow the students to connect their personal experiences
involving fire to the material learned, several problem-solving and investigative activities were performed. This allowed students to use their daily experiences to take ownership of their learning and collaborate with their peers on a level that is familiar to them (Stears, 2009, p. 404). Upon the completion of the lesson each day, focus group interviews involving five different learners were conducted to allow students to further reflect on the lesson and allow for the related social issues to be heard. Each learner was instructed to speak in English the best that they could, otherwise a translator was provided for them. It was evident from the interviews that connecting everyday experiences to what the students are learning allowed them to feel confident about the material and find ways to apply it to their daily life. For example, students reflected upon what they learned by stating that they are grateful that they are now aware of the behavior of fire as well as methods to dull or put out a fire. Not only did the lesson allow students to take ownership of their knowledge, but it increased the teacher’s awareness of what occurs in these students’ daily lives and how it affects them (Stears, 2009, p. 406).

Although this study demonstrated how a constructivist approach can permit students to find value in scientific content through the implementation of personal connections, this does not generalize all populations. Stears (2009) states that this study can be limited to offering a greater benefit to schools that educate students of similar backgrounds and upbringings as the South African population of students (p. 407). Additionally, many student responses and interviews were translated since most of the students preferred to speak in their mother tongue. Due to this language barrier, many reflective responses were not precisely reported causing a loss in important information in the translation process (Stears, 2009, p. 407). Lastly, interviewing children can present problems considering it is natural for a child to answer questions with what they believe is a correct answer as opposed to their own answer. To reduce the possibility of this
bias, the learners were interviewed multiple times (Stears, 2009, p. 408).

It is difficult to generalize a curriculum that is universal to all students when they come from a variety of backgrounds. Therefore, it is implied that if science education does not take this into account, the chance of positive learning outcome is slim. Although a change in a school’s structure can be problematic, the implementation of a constructivist approach in the classroom can increase the chances for a positive change to occur when teaching content. Since the situations the students in this study face are not abnormal for South Africa, it is suggested that the teachers in this country develop counseling skills to discover different ways to connect with their students on a more personal level to enhance their learning (Stears, 2009, p. 407).

The idea of constructivism has been working its way into the framework of education since 1982. With the increasing awareness of the limitations that traditional teaching methods possess, nations have been putting forth effort for educational reforms (Feyzioglu, 2012, p. 302). Constructivist approaches embrace the idea that students create their own concepts through their experiences with their physical and social environment as opposed to learning ideas directly from a teach or a textbook through traditional methods (Feyzioglu, 2012, p. 302).

In 2005, a new science and technology program has been implemented in Turkey that calls for the use of constructivism in the classroom. Although it is expected for science teachers to maintain the belief and adhere to the beliefs of constructivism in the classroom, this study aims to address whether teachers believe in this system (Feyzioglu, 2012, p. 302). Feyziogly (2012) believes that a system of constructivism is most successful when teachers believe in the practice (p. 303). Therefore, determining the beliefs of teachers is a mental representation of all of their conscious and unconscious attitudes towards constructivism.

This study involved 18 teachers in Turkey with professional experience varying from 3 to
27 years. These teachers taught students in sixth, seventh and eighth grade. To examine the beliefs of the teachers, Feyzioglu (2012) interviewed each teacher for forty minutes and asked about their beliefs in teaching, learning and managing behavior problems (p. 306). The questions chosen by the researcher directly garnered ideas about the teacher’s direct beliefs and indirectly gathered insight into their beliefs by constructing questions about possible classroom scenarios. Based upon the teachers’ responses, they were classified as an educator with traditional, transitive or constructivist beliefs about teaching science (Feyzioglu, 2012, p. 306).

The findings show that teachers with traditional beliefs feel that students should be good listeners and memorize and repeat what is learned to best learn the content. In terms of classroom management, students are instructed to be silent during a lesson, follow all verbal directions during laboratory procedures and decrease noise during group work (Feyzioglu, 2012, p. 308). However, teachers with constructivists beliefs stated that the primary focus of science teaching is making sure that students are active learners in the classroom. The students should be guided through instruction rather than given instruction to allow them to construct knowledge on their own (Feyzioglu, 2012, p. 309). Teachers with constructivist beliefs place major emphasis on creating a connection between the students’ daily lives and scientific concepts. To make this connection, discussion among students as well as learning from misconceptions is encouraged by the teachers. Teachers with a constructivist approach expressed that misconceptions are a way to guide student learning through trial and error and increase conceptual understanding. These teachers believed that when students take ownership of their work and can freely choose how to learn, there will be less management problems (Feyzioglu, 2012, p. 310).

Due to many varying responses in the teacher interviews, a category was created for teachers with transitive beliefs. This involved teachers that valued the concepts of engaging
experiments, high levels of participation and strong connections between science and everyday life while simultaneously implementing traditional classroom practices that were not in line with a constructivist approach (Feyzioglu, 2012, p. 309). These teachers expressed in their interviews that they inculcate the value of scientific curiosity, making connections and constructing useful knowledge in their students. In addition to these constructivist approaches, they share sentiments with traditional teachers. They believe that misconceptions can often be disrupting rather than a teachable moment, students are extremely noisy and unfocused when working in lab groups and it is very difficult to teach students how to construct their own knowledge (Feyzioglu, 2012, p. 309). Teachers with transitive beliefs value constructivist ideas, but due to the lack of resources, large class sizes and lack of time to complete the mandatory curriculum they feel the need to implement traditional methods (Feyzioglu, 2012, p. 308).

To quantify the results from the teacher interviews, Feyzioglu (2012) coded the responses based on specific key words to categorize each teacher into their specified belief category of either traditional, transitive and constructivist (p. 311). The findings were further disaggregated based on years of experience. According to the interview responses, the teachers with 1-10 years of experience held mainly constructivist beliefs when teaching science and managing behavior problems. As the years of professional teaching experience increased from 11 years or more, teachers mainly had a transitive approach in teaching science and a traditional approach in managing behavior problems (Feyzioglu, 2012, p. 311). It is evident that when a teacher encounters classroom difficulties or possesses more years of teaching experience, there is a shift in the belief that students should be “hands on and minds on” environment to one that is more teacher centered (Feyzioglu, 2012, p. 313).

Although this study demonstrated that teacher beliefs contradict the constructivist
approach implemented by the school, the sample size was small. Expanding this study to more
than two cities in Turkey and even further across countries, there can be a larger generalization
made about the beliefs of teachers compared to the beliefs of schools. Additionally, this study
limited its data collection to teacher interviews. Although the interviews were lengthy and gave
insight into each teacher’s beliefs, they do not offer direct evidence of what is occurring in the
classroom (Feyzioglu, 2012, p. 314). Conducting observations could offer a deeper
understanding about how classrooms are managed and how instruction is carried out based on
the teacher’s beliefs.

Implementing a curriculum that is based on constructivist beliefs is difficult when
teachers are not given sufficient resources, time and opportunities to understand and familiarize
themselves with the new approach. Therefore, it is suggested to offer professional development
programs for teachers since many still value traditional approaches. Feyzioglu (2012) also
questions whether or not professional development would even be beneficial for teachers with
advanced professional experience when they still possess deeply rooted beliefs in traditional
approached (p. 314). However, allowing teachers with varying years of experience to collaborate
and discuss how to manage certain classroom issues, there is a greater change that many of them
will hold on to their constructivist beliefs rather than surrender them when they encounter these
difficulties again (Feyzioglu, 2012, p. 314).

While classrooms have begun to become more diverse, science instruction has remained
traditional in its approach. Constructivism and culturally relevant pedagogy are two theories
frequently identified as methods to decrease inequalities in science education (Patchen & Cox-
Petersen, 2008, p. 994). For students that are marginalized from the typical schooling process, it
is difficult for them to cross the border between real life experience to classroom experiences.
This has caused science to resonate more with middle-class white students compared to students of varying ethnic, socioeconomic and linguistic backgrounds (Patchen & Cox-Petersen, 2008, p. 995). To narrow this gap, it is suggested that teachers offer opportunities for their students to link their community to their classroom experiences to boost metacognitive processes and increase their learning despite their limitations. This study posed the question “How can constructivist practices inform and/or support culturally relevant practice in today’s increasingly culturally diverse classrooms?” (Patchen & Cox-Petersen, 2008, p. 995).

Constructivism recognizes instruction that is learner centered and encourages teachers to guide knowledge instruction rather than transmit the information. Students will take an active role in a constructivist environment and will focus on cognitive strategies, hands-on experiences and reflections that will enhance their learning and development (Patchen & Cox-Petersen, 2008, p. 996). Culturally relevant pedagogy also aims to focus on making constant connections in the classroom environment, however it further addresses the idea of increasing awareness of a student’s linguistic and cultural experiences to recognize power relations. Adopting a culturally relevant pedagogy presents many challenges for teachers if they are unable to make a connection between the curriculum and their student’s languages and cultures (Patchen & Cox-Petersen, 2008, p. 999).

This study took place in Los Angeles, California and involved two white female teachers and their inner-city Latino and African American class populations. One of the teachers involved, Veronica, has been teaching for 14 years and her science class consisted of fourth-grade Spanish speaking students. The other teacher, Heather, teaches second and third grade science as an integrated part of the core curriculum. She is a fifth-year teacher and frequently partakes in professional development programs related to science. (Patchen & Cox-Petersen,
2008, p. 1000). Each teacher was observed ten times during a six-week period and specific instructional strategies were recorded through video, audio and fieldnotes. In addition to observations, five interviews were conducted after observations (Patchen & Cox-Petersen, 2008, p. 1000).

It was evident through the observations of Veronica and Heather that they both access student’s prior knowledge and experience to guide their learning. Both teachers also made it a point to provide opportunities or students to connect their daily experience to scientific concepts. Regardless of the type of instruction carried out by both teachers, their classes were inclusive, participatory and aligned to constructivist ideals (Patchen & Cox-Petersen, 2008, p. 1008). Although constructivist strategies were frequently utilized in the classroom, the observations demonstrated that students typically did not construct their own knowledge. It was rare that students were presented with opportunities to reflect upon their learning and the teachers seldom documented whether knowledge construction occurred. Teachers would offer probing questions and activate prior knowledge, however the connection between personal experiences to the curriculum was frequently determined by the teacher. This made it unclear whether students understood the connections they were making since they heavily relied on the views of their teacher (Patchen & Cox-Petersen, 2008, p. 1009). Although the teachers value a constructivist approach in their teaching methods, it was observed that they typically encapsulated a more traditional approach in their methods.

It may seem like education is getting closer to producing a culturally relevant practice, however we are still falling short. The data collected in this study revealed that there is still quite a gap between social constructivism and culturally relevant pedagogy, however teachers are becoming aware of how important it is to build upon student experiences by considering their
language and backgrounds when implementing instruction (Patchen & Cox-Petersen, 2008, p. 1009). Although Veronica and Heather value student participation and the fundamentals of constructivism, they both rarely expanded upon student reflections and contributions to further their learning. This lack of oral participation and unvaried questioning structure does not support the development of the critical thinking skills required to balance authority, make connections outside of the classroom and progress towards a culturally relevant pedagogy (Patchen & Cox-Petersen, 2008, p. 1000).

Expanding this study to involve more diverse districts and include many more teachers of different grade levels could help further the generalization that this study sought out to support. Although this study was limited to two elementary school teachers in an inner-city school district, several methods are suggested to begin making changes in the classroom to be more constructive and culturally responsive. One implication is that teachers should carefully reflect on their own practice by videotaping themselves to observe their teaching methods. This can allow the teachers to visually see whether their instruction is connected to their beliefs (Patchen & Cox-Petersen, 2008, p. 1011). Teachers are also encouraged to communicate with their students in active conversations to get to know their students at a deeper and more cultural level. Establishing a relationship with the students in the classroom allows for teachers to integrate the students’ various experiences into class instruction, which helps reflect a culturally relevant pedagogy (Patchen & Cox-Petersen, 2008, p. 1011). By allowing for more opportunities for students to engage in a constructive and culturally relevant environment, science can suit students from more diverse backgrounds and encourage students to take ownership of their learning.
Augmented Reality

Many students possess misconceptions about various scientific ideas. To ameliorate the challenges that students face when learning difficult scientific concepts, researchers look to utilizing augmented reality (Yoon, Anderson, Lin & Elinich, 2017, p. 156). Many aspects of augmented reality allow for the replication of real world environments that are not typically tangible to students. Augmented reality allows students to manipulate content while engaging themselves in scientific inquiry, make observations and collaborate with peers. In this study, Yoon et al. (2017) use augmented reality to provide students with a more accurate understanding of Bernoulli’s principle (p. 158). The specific tool used in this study is called the “Bernoulli Blower,” which allows students to visualize a reaction between two types of air to keep a plastic ball floating in the air (Yoon et al., 2017, p. 159).

This study was carried out in a large museum in a northeastern U.S city consisting of 58 students that were chosen by their teachers. The student participants were in grades 6, 7 and 8 and made up a population comprised of 41% male students and 59% female students from three charter schools and two public schools. Students in grades 6-8 were chosen for this study since each student received prior instruction about Bernoulli’s principle in fifth grade (Yoon et al., 2017, p. 160). Upon the arrival to the museum, students were randomly assigned to two groups. One group received the non-augmented reality conditions while the other group received the augmented reality condition. Each group received the same task, which was to make a red ball float. Once they accomplished the task, each student was individually interviewed about their experience with the augmented reality device. The next day, researchers traveled to the schools and issued a post-intervention survey to the students to determine their knowledge. The results indicated that the students in the non-augmented reality group had 29 students that spent an
average of 11 minutes and 43 seconds trying to make the ball float. Contrastingly, the augmented reality group also had 29 students but spent an average of 9 minutes and 41 seconds trying to make the ball float (Yoon et al., 2017, p. 160).

To collect qualitative data about the student’s knowledge, a pre and post survey was distributed to the students. The surveys consisted of four multiple choice questions and one open ended response question and the student responses were coded and converted to a Likert scale with a continuum of limited to complete understanding (Yoon et al., 2017, p. 161). The survey results demonstrated that the students exposed to augmented reality scored much higher than those who were not exposed to augmented reality devices. Similarly, the results of the oral interviews between the students and the researchers revealed that digital augmentation had a very positive effect on the content knowledge of the students (Yoon et al., 2017, p. 162). The students expressed in their interviews that the augmented reality devices allowed them to experience phenomena that they were not able to while reading a textbook. This allowed them to build an understanding of Bernoulli’s principle they typically would not be able to when delivered by traditional means (Yoon et al., 2017, p. 163).

Although this study supports that augmented reality can enhance learning, Yoon et al. (2017) explains that the results show “modest conceptual gains” (p. 163). The difference between the two student groups showed that there was an improvement of less than a level on the knowledge survey when exposed to augmented reality. It would be beneficial for further research to include additional ways to scaffold the augmented reality experience to bring forth greater learning (Yoon et al., 2017, p. 163). While the study states that the students involved in this study were selected by their teachers, there is no explanation about how the students were chosen. The sample of students used was a relatively small sample considering the goal of the
The study was to make a generalization about how augmented reality positively influences student learning. Further suggestions could be to utilize a larger sample size of students and specify the criteria for which they chose the participants. Additionally, the students involved in this study had prior knowledge of the principle being taught. It would be interesting to see if augmented reality has a positive impact on concepts that students have not learned yet. Since these students ranged from 6th to 8th grade students, their prior knowledge and retention of Bernoulli’s principle varied. Limiting the study to include one specific grade level with the same amount of background knowledge may serve as a better control compared to using multiple grade levels.

**Persuasive Graphic Organizers**

Connecting real world experiences to concepts taught in the science classroom is essential for students to make sense of their learning. Implementing a socioscientific approach in the classroom initiates critical thinking in students and allows them to reflect on scientific problems they can connect to real life (Halim & Mohd Saat, 2017, p. 813). It has become harder for students to visualize complex ideas in science and derive knowledge from what they learn, which prevents them from being able to properly evaluate scientific evidence. The goal of this study was to allow students to connect their learning to socioscientific issues using persuasive graphic organizers.

This study consisted of 36 students that were members of the Science and Mathematics Society at a Residential School in Kuala Lumpur, Malaysia. The students were from various backgrounds and were selected for this study based on their fundamental knowledge of global warming, their level of interest in discussing the issue and their ability to express scientific and social perspectives about socioscientific issues (Halim & Mohd Saat, 2017, p. 815). The researchers in this study instructed the students to work in six different groups to create
persuasive graphic organizers. The organizer consisted of two parts, one that describes the scenario at hand and one that involves a decision-making process. The goal of these organizers is to allow the students to create an influential and argumentative narrative that educates the reader about the issue while simultaneously persuading them about the need to solve the problem (Halim & Mohd Saat, 2017, p. 816).

The data collected in this study consisted of twelve persuasive graphic organizers as well as interviews. When analyzing the data, the researchers sought out to see if the students could identify the anthropogenic factors affecting global warming, if they could clarify the effects of global warming and if they could offer alternative solutions for more environmentally friendly technologies (Halim & Mohd Saat, 2017, p. 817). Based on the interviews, it was evident that students felt that the persuasive graphic organizers were relevant and workable in terms of helping them identify key concepts about global warming. The graphic organizer allowed the students to use their knowledge to make informed and logical decisions about the socioscientific issue of global warming and create solutions to world problems (Halim & Mohd Saat, 2017, p. 820). One of the major benefits of graphic organizers is that it allows students to think visibly which can enhance ongoing thoughts and strengthen reflections that students can make about a concept they learned (Halim & Mohd Saat, 2017, p. 820).

The analysis of the graphic organizers indicated that the students were able to utilize their understanding of the cause and effect of global warming and connect it to more than one solution to address the crisis. Halim & Mohd Saat (2017) suggest that persuasive graphic organizers should be used to not only help students with their decision-making skills but to offer them visible guidance to enhance their understanding and motivation (p. 321). Although this study demonstrated the positive effect that graphic organizers had on the students’ visual thinking and
their ability to discover relationships between evidences and decisions, this does not generalize a
typical student population. The students for this study were hand selected based on their higher
prior knowledge and increased interest in the topic compared to their peers. Since these students
demonstrated a high level of prior knowledge, they were able to further connect their
understanding to real world solutions. This supports that persuasive graphic organizers are better
used as a tool when students have a very concrete understanding in the material rather than
minimal understanding in order to be most effective (Halim & Mohd Saat, 2017, p. 821).
Additionally, the interviews and persuasive graphic organizers needed to be translated from
Malaysian into English. Translation could add an element of inaccuracy considering every single
word that was verbally expressed or written may not have been properly translated.

Halim & Mohd Saat (2017) suggest that it would be beneficial to utilize persuasive
graphic organizers to unveil student misconceptions about a topic. Most of the time, the reason
why students cannot connect their learning to proper real-world scenarios and solutions to
scientific problems is because of their deeply rooted misconceptions. These graphic organizers
would be a helpful way for teachers to determine which misconceptions prompted a student to
create an incorrect solution to a global problem. Since this study was limited to a small
population of 36 students in grades 7-9, this study could be considered more valid by including
more students and various grade levels. Furthermore, it would be interesting to see if persuasive
graphic organizers could function as a tool that students could do before and after a lesson to
assess the increase in their understanding of a concept and whether or not they are able to relate
it to real world issues.
Experiential Augmented and Virtual Reality

Recently, there has been a shift in education from two dimensional images and videos to more engaging and interactive learning environments. Science requires knowledge acquisition that is experiential, self-directed and hands-on, therefore creating a virtual learning environment is beneficial for the students (Birt, Stromberga, Cowling & Moro, 2018, p. 1). There has been an increased shift in higher education from a face-to-face learning experience to a more online and self-directed experience. In addition, there is a strong advocacy towards providing learners with simulations to guide their learning experience as it improves their competence and skills. Various technologies such as augmented reality (AR), haptic virtual reality (VR) and mobile devices are providing students with the necessary means to enhance their learning environment (Birt et al., 2018, p. 1).

There has been a surge in online student enrollment in the field of science. Students in the medical field are required to learn a vast amount of information through their online courses and the universities are required to provide this content in the most efficient manner possible (Birt et al., 2018, p. 2). Recently, some universities are shifting away from textbook driven instruction to virtual platforms where students can instantly engage with learning that is experiential. Much of the software the students will be using in this study focuses training them in a specific task and developing automatic skills while decreasing their cognitive load. This in turn is linked to enhanced learning outcomes (Birt et al., 2018, p. 3).

In this study, the first intervention used on higher education health students in Australia focuses on knowledge and learner perceptions, while the second is focused on learned skills. For both interventions, a Google program called Unity 3D was utilized as well as Samsung Gear VR was used (Birt et al., 2018, p. 4). In the knowledge and student perception intervention, 46
anatomy and physiology students participated in lessons on the brain and spinal cord and provided feedback on their AR and VR learning experience. This module used 3D models for the brain, spinal cord and brainstem through various pacing with narration (Birt et al., 2018, p. 5). For the skills development intervention, 159 paramedic students participated. This intervention required the students to take a pre-test on the material, however both interventions required students to make qualitative comments and required staff to make observations and partake in interviews (Birt et al., 2018, p. 8).

It is evident from the results that students require support and scaffolding in health and medical education courses, especially if the courses are delivered through the internet. To aid this support, educators should develop these strategies by transmitting content to students through more engaging and challenging ways while still supporting the pedagogy (Birt et al., 2018, p. 11). Both interventions provided learners with improved experiential learning, reduced cognitive load and implemented functional task alignment by focusing on human functional factors such as task, learning stage, content, ability and other instructional features to transfer learning (Birt et al., 2018, p. 11). Additionally, students expressed that the virtual reality software provided engaging narrations that the students were better able to memorize compared to lecture style learning. These narrated guides through the visual and interactive human body system taught the students the content in a way that was conversational and casual yet still delivered the instruction. This method also allowed students to be self-paced, which increased their self-efficacy and independence (Birt et al., 2018, p. 11). The interventions both provided mixed reality technologies that allowed students to learn skills at a distance but still allowed them to feel involved and interactive.

Both interventions provided students with mobile, augmented, virtual and haptic
feedback that had no negative effect on their learning. Although it was mobile and not as powerful as a desktop application, the simulations proved to significantly increase the competence and skills of the students (Birt et al., 2018, p. 11). Mixed reality learning experiences allow students to have control over their learning and tackle challenges at their own pace. Many virtual and augmented reality technologies are costly, however with the ability to deliver this type of mixed reality through mobile devices decreases the cost and still allows for the learning goals to be transferred to the students.

**Virtual Reality Learning Environment and Student Perception**

Virtual reality learning environments allows for the visualization of data that is three dimensional and to reinforce information using interactive sense and touch feedback. The most common use of virtual reality is to provide an environment for learners that mimics the real world in a safe manner (Huang, Rauch & Liaw, 2010, p. 1171). One of the goals of virtual reality is to allow students to be immersed in their learning environment. Physical immersion is accomplished through using visual, auditory and haptic cues to obtain information while controlling objects in the virtual environment. Mental immersion on the other hand involves the deep engagement with the virtual environment (Huang, Rauch & Liaw, 2010, p. 1172). Therefore, educators would like their students to be both physically and mentally immersed in the virtual environment for the most successful experience.

The goal of this study was to survey the attitudes of learners toward virtual reality learning environment and whether the features of immersion, interaction and imagination have a positive impact on collaborative learning. This study involved 76 student participants consisting of 48 males and 28 females. The students interacted with a software called 3D Human Organ Learning System- 3D-HOLS which allowed them to obtain knowledge about the human body.
After a month of use, the students completed a 7-point Likert scale survey, which asked the students about their attitudes toward the virtual reality learning environment (Huang, Rauch & Liaw, 2010, p. 1176).

Based on the survey results, it was evident that in order for a virtual reality environment to be conducive towards learning, the activities must be designed in an appropriate manner and certain principles must be taken into consideration (Huang, Rauch & Liaw, 2010, p. 1179). In this study, virtual reality was intended to have a fundamental constructivist approach. This would allow the students to absorb the information learned in the virtual reality simulation and connect it with prior knowledge to construct new knowledge (Huang, Rauch & Liaw, 2010, p. 1173). The results from both surveys indicated that interaction with a realistic virtual environment is essential when obtaining information and making connections. This immersive environment created a strong sense of presence for the students and increased their motivation, which allowed them to process material more deeply (Huang, Rauch & Liaw, 2010, p. 1173).

Huang, Rauch & Liaw (2010) suggested that a virtual reality environment is imperative for allowing learners to receive an individualized experience. Virtual reality gives students feedback in a haptic or sensory manner to indicate when they are performing a task correctly or incorrectly (1174). The results from the survey indicated that the virtual reality learning environment provoked students to develop independent thinking abilities and engage in collaborative learning (Huang, Rauch & Liaw, 2010, p. 1179). It can be inferred that a virtual reality learning environment requires students to conceptualize abstract ideas. Therefore, immersion, interaction and imagination all serve as positive factors for enhancing problem solving and analysis in virtual learning environment (Huang, Rauch & Liaw, 2010, p. 1179). Lastly, motivation was classified to be a major factor that impacts student learning. It was
evident that the student’s interaction with virtual reality technology offered lifelike experiences that motivated students and allowed them to improve their knowledge and retention (Huang, Rauch & Liaw, 2010, p. 1179).

Although virtual reality technology offered students the ability to construct knowledge, think independently, work collaboratively with peers and increase their retention, there are some limitations to its use. Often, virtual reality comes with software issues mainly involving the 3D interface. The results of the survey indicated that this caused some of the learners to become frustrated, lost or unable to navigate their virtual learning environment (Huang, Rauch & Liaw, 2010, p. 1180). Student perception is important as it can affect how much they are willing to immerse themselves in a new learning environment. There is a positive correlation between student perception, motivation and immersion when working in virtual learning environments and it is evident that the information that is presented to students in this learning environment has a positive impact on their retention rate as well as their ability to construct knowledge.

There is an increased interest in online education for students as opposed to traditional campus learning environments. With increased enrollment, universities understand the need for e-learning environments as well as online collaboration with classmates. A key component of online education is that students can interact with one another as well as the teacher in ways that are not task specific, as this comes more naturally with face-to-face interaction. Recently, there has been an increased interest in utilizing avatars in a 3D environment in which students can interact with each other and experience haptic feedback through touch sensation (Petrakou, 2010, p. 1020).

An important aspect of education is that students are able to interact with one another. The goal of this study is to explore how virtual worlds can facilitate instruction and to also
identify issues of interactivity (Petrakou, 2010, p. 1021). This study involved seven students that were enrolled in an English proficiency course utilizing a 3D virtual world called Second Life. Second life allows students to become avatars, explore a virtual world they may not normally be able to experience, socialize and collaborate with others and engage in endeavors. Throughout this experiment, students completed five two-hour sessions in which they performed specific tasks and exercises that initiated language practice (Petrakou, 2010, p. 1021).

To observe the virtual sessions and student interactions, an observational avatar was created and participated in each of the five Second Life sessions. Virtual recordings were also taken through a teacher computer, and the students were also observed in the real world setting as well while interacting with the program. To supplement the observations, teachers also conducted interviews with the students to gain a better understanding of the student’s perceptions of the program (Petrakou, 2010, p. 1021). Throughout the sessions, the course launch, virtual sessions and time spent in between sessions were studied to identify any issues related to teacher-student and student-student interactions. Since this was a new activity for students, researchers wanted to observe how students reacted to a new learning environment, new social norms, new navigation skills and new methods of interaction (Petrakou, 2010, p. 1022).

There has been extensive support advocating for synchronous communication in online education as it improves teacher-student feedback and fosters student-student relationships. This study showed that the virtual world provided the students with a synchronous community through chat functions, exploratory functions and voice functions to navigate, interact and indulge in sensory experiences (Petrakou, 2010, p. 1025). Since everything was virtual, the teacher could explain instructions or phenomena either in person or through the observational avatar. The teacher was able to explain concepts using the avatar’s world and encourage
communication and collaboration amongst the students. Many experiences in the virtual campus mimic that of a real-life campus environment, therefore the opportunity to interact in a virtual world through online education may be just as valuable as on campus interactions (Petrakou, 2010, p. 1026).

A majority of the collaboration among students in the beginning of the lab was talking about being in a virtual world. The students were observed asking each other questions about how to live in the world, fly, walk, run and talk. This interaction allowed the students to become more familiar with each other and lead to further collaboration throughout the sessions (Petrakou, 2010, p. 1026). One of the difficulties that researchers observed was the students’ ability to refrain from relying on their real-world conceptions in the virtual environment. Students often question the abilities of the virtual world as they were not accustomed to the virtual world’s capabilities and new norms. However, with more frequent use, students were able to capitalize on the unique experience offered to them and experience a world that they typically cannot in their normal life (Petrakou, 2010, p. 1026).

Virtual worlds provide students with experiential interactivity with a spatial dimension. Although there can be many technical difficulties that can arise with this type of software, the challenges must be overcome to allow the leaners to further develop their skills (Petrakou, 2010, p. 1027). Virtual environments allow students to explore diverse activities while collaborating with their classmates, which increases socialization among students in a positive way. Being able to collaborate with peers has had a positive correlation with learning new course content and discovering ideas that are not traditionally familiar to students. Although virtual environments are effective, they should be used as a supplement to knowledge construction.
Computer games have become an easily accessible and main part of the social and cultural environment and entice many people in a variety of ways. With student motivation identified as one of the most difficult aspects of teaching, it is hypothesized that using video games in the classroom can increase student engagement and result in better learning and achievement (Wrezesien & Raya, 2010, p. 178). Aside from motivation, it is important for students to be able to construct their own knowledge to reach a more complex level of understanding. The construction of one’s own knowledge can be based on the perceptual exchange and experimental interactions that a user experiences with an object (Wrezesien & Raya, 2010, p. 178). The combination of educational content with computer games can be defines as serious games (SGs), which integrates gaming elements with learning objectives to increase a student’s ability to understand curricular content through a constructivist approach (Wrezesien & Raya, 2010, p. 178).

When used in education, gaming creates personal motivation and satisfaction, reinforces skill mastery, accommodates many learning styles and provides a context for interactive decision-making which helps student develop cognitive skills (Wrezesien & Raya, 2010, p. 179). E-Junior is a serious virtual world that follows a Spanish natural science and environment curriculum and introduces students to the foundational knowledge of natural science and ecology. The goal of this study is to determine if E-Junior can encourage active learning in a technologically immersive, interactive, fun and innovate environment (Wrezesien & Raya, 2010, p. 179).

This study consisted of 48 student participants separated into a control group, receiving traditional instruction and an experimental group receiving instruction from E-Junior (Wrezesien & Raya, 2010, p. 181). The experimental group engaged in the E-Junior modules that allowed
them to explore the Mediterranean sea’s aquatic environment. The module consisted of an introduction to the universe, Earth and the environment, an introduction to the Mediterranean Sea’s ecosystem and an explanation of the game’s rules before the students selected their fish avatar that they would then utilize to explore and experience the virtual aquatic world (Wrezesien & Raya, 2010, p. 180). The hypothesis formulated for this study was that students in the virtual group would demonstrate a greater learning performance in natural science and ecology compared to those receiving traditional instruction. Additionally, it was hypothesized that student evaluations would demonstrate that virtual classroom experiences have a greater appeal to students compared to traditional instruction (Wrezesien & Raya, 2010, p. 181).

Prior to engaging in the virtual world, students took a pre-test that assessed their knowledge on natural science and ecology. After the intervention, students completed a post-test and close-ended questionnaire was distributed to students to measure knowledge gains as well as the level of virtual appeal to students (Wrezesien & Raya, 2010, p. 182). Based on the results, there was no statistical differences in the learning performance between the two research groups.

It can be inferred that the innovative environment can be a distraction to some students which can impede the possibility of increased learning. However, the students that participated in the virtual environment reported that they enjoyed class more and were more engaged than the students in the traditional learning environment (Wrezesien & Raya, 2010, p. 184). These results suggest that the utilization of E-Junior could serve to supplement traditional instruction and to enhance experiential learning when field trips are not feasible. Conversely, although this could not replace the experience of an actual field trip, it could also serve as a tool to prepare for or review material prior to a field trip (Wrezesien & Raya, 2010, p. 185).

As a result, using serious virtual worlds is an effective way to engage and motivate
students. Since there was not a significant increase in learning gains between the virtual and traditional environments, further improvements can be made to determine more specific effects of virtual environments on student knowledge. Being motivated is a facet of teaching that is difficult to promote, which in turn can cause a lack of interest and a halt in comprehension. Allowing students to engage in virtual worlds can increase their motivation while simultaneously exposing them to an environment that is otherwise intangible.

**Haptics and Virtual Reality**

Haptic is defined by the sense of touch and involves the science of incorporating this with the external environment through touch (San Diego, Cox, Quinn, Newton & Banerjee, 2012, p. 156). Although the use and research of haptics is sparse in comparison to other topics, it is becoming widely accepted in education, especially for teaching clinical concepts and training medical students prior to practicing on humans (San Diego et al., 2012, 157). The usage of advanced simulation environments provides students with a powerful and flexible medium to increase their learning and experience a wide range of manipulation skills (San Diego et al., 2012, 157). The focus of this study involves a project called hapTEL, whose goal is to investigate the impact of haptics on student learning, specifically when learning the dental curriculum (San Diego et al., 2012, 159).

The hapTEL project development involved the investigation of three different areas. The first area involved the technical development and evaluation of the hapTEL workstation, which mimics clinical conditions for students in dental school (San Diego et al., 2012, 159). To do this, a group of dental clinical teachers collaborated to determine how they feel their students would learn from this technology and what possible constraints may exist. Through collaboration and consultation with their students, 144 students believed that a simple haptic system would be
suitable when learning about dental concepts such as cavity preparation procedures (San Diego et al., 2012, 160). The second area involved the examination of the undergraduate and postgraduate dental curriculum to determine how these students could benefit from the use of haptics. Students reported that the hapTEL laboratory systems is beneficial for decreasing their cognitive load and increasing their contact time with essential medical practices whenever necessary (San Diego et al., 2012, 161). Lastly, the researchers evaluated the impact of the work carried out by the first and second areas of study. This third area specifically focused on the student and teacher attitudes, learning experiences and learning outcomes.

To quantitatively measure the hapTEL outcomes of the 144 student participants who believed that haptics would impact their learning positively, a pre and post-test was distributed to them in between learning modules for two consecutive years. To qualitatively measure their learning experience, students were interviewed, video observations were recorded, and classroom conversations were transcribed (San Diego et al., 2012, 162). When evaluating hapTEL for teaching and learning, it is suggested that educators need to identify the different design features of the technology as well as establish how the students will interact with the learning environment so there can be a clear explanation of what is most effective (San Diego et al., 2012, 164). By studying the three designated areas of research, the results from the project demonstrated that factors that may have been overlooked in a more limited study had drastic impacts on the ease, integration and sustained use of the technology. Therefore, studying the specific areas of hapTEL helped prevent influential variables being overlooked and there is an interrelationship amongst the development of technology, the gradual change of the curriculum and student feedback on the instructional methods used (San Diego et al., 2012, 164).

Although haptics increases a students’ ease of access to the curriculum, especially a
curriculum for a dental student that requires manipulation of human teeth, there are some limitations to the software. It is important that educators consider that student attitudes towards the use of haptic software can impact their application. If students are entering a class expecting to interact with actual dental devices such as drills, they may not be receptive to using virtual devices as a medium for practicing skills (San Diego et al., 2012, 165). It is important for educators to note that if haptic feedback is utilized, it is used to supplement traditional and more mandatory practices in order to enhance the curriculum.

The combination of both virtual reality and force-feedback is a proposed teaching aid to help students grasp the understanding of phenomena that is nano-physical and non-intuitive. The specific concept studied in this research is the behavior of an Atomic Force Microscope (AFM) (Millet, Lécuyer, Burkhardt, Haliyo & Régnier, 2013, p. 608). The Atomic Force Microscope is a tool that images, measures and manipulates matter and nano-objects so one can calculate forces that are at play between the microscope’s probe, called a cantilever, and a sample. To enhance this technique, virtual reality and haptic feedback have been developed to enhance a user’s 3D view and receive force feedback (Millet et al., 2013, p. 608). Haptic perception is based on inputs from mechanoreceptors and thermoreceptor subsystems in the skin coupled with position and force sensing mechanisms in the muscles and joints. By implementing haptics into virtual reality, users are able to extract information through the tangible exploration of objects (Millet et al., 2013, p. 610). By allowing learners to manipulate objects by controlling them with their hands, haptics and graphic representations provides dual communication between the learner and the system to enhance active exploration and increase learner performance (Millet et al., 2013, p. 610).

A large part of understanding science is to allow learners to make sense of the material
they are being exposed to by being able to interact with the subjects and their environment while problem solving and exploring (Millet et al., 2013, p. 611). To determine the impact environmental interaction has on students, this study seeks to understand if the addition of haptic feedback results in a better understanding compared to providing only graphic representation. To test this, four groups were created consisting of a group with haptics, without haptics, with realistic analogical representation of graphics and one without (Millet et al., 2013, p. 612). Forty-five engineering students, 41 males and 4 females, manipulated and experience the mechanics of the AFM probe when it comes in contact with a sample surface. The students were asked to carry out three tasks that required them to construct of a verbal representation of the phenomena, a translation from sensory perceptual process to drawings and were also asked to problem solve (Millet et al., 2013, p. 616).

Based on the feedback from the participants, the haptic feature of the experiment was more influential compared to the analogical graphic representation of what was being studied. Although the haptic features were the most helpful, all students preferred the condition receiving haptic feedback along with graphical representation (Millet et al., 2013, p. 622). It was evident that the students who received haptic conditions had a better understanding of the phenomena than the groups without haptics. These students also spent more time testing, drawing and answering questions during the simulation (Millet et al., 2013, p. 622). Some reasoning behind the haptic feedback being the most successful was that it was more engaging and it also allowed the students to orient and explore their subjects in a relevant manner. Receiving haptic feedback also presented students with sensory information that allowed them to focus and explain their reasonings behind the mechanics of the concept they were studying (Millet et al., 2013, p. 623).

Although haptics provided students with sensory inputs, students also were able to use
graphical representations to focus on physical characteristics of the material being studied as well. Working together, haptic and visual technology can offer students a way to decrease the excess processing time and increase their ability to build mental models (Millet et al., 2013, p. 623). Utilizing both technological features was perceived by the students as something that had a positive influence on their learning. In a non-virtual environment, students cannot manipulate forces due to realistic limitations. The haptic feature of the model increased the attention on forces while also improving the perception of the influence of physical parameters. The graphical analogies also increased the students’ abilities to connect phenomena presented in an augmented manner to events that occur in the real world (Millet et al., 2013, p. 624). In the future, it would be interesting to see the effects of haptic feedback on acquiring new knowledge over a longer period of time to see how the implementation of haptics increases retention.

The utilization of simulations generated by a computer to enhance microworlds is an ideal method to increase active engagement in the classroom when learning complex scientific concepts. With the addition of haptics, which is tactile and kinesthetic feedback, the user’s ability to interact with the virtual environment is enhanced (Minogue & Jones, 2009, p. 1359). The goal of this study is to examine the Student Observed Learning Outcome (SOLO) taxonomy developed by Biggs and Collis as a method to assess student learning about cell transport while using a computer program. Another goal of the study is to determine if the addition of haptic feedback can detect differences in understanding (Minogue & Jones, 2009, p. 1360).

SOLO taxonomy allows educators to classify and describe the range of performances among learners when executing a particular activity. The SOLO model describes five levels of sophistication, the first being Prestructural, which indicates no understanding. Unistructural and Multistructural indicate a surface level understanding of facts and Relational and Extended
Abstract suggest a change in the quality of responses going beyond given information (Minogue & Jones, 2009, p. 1361). The reason why the SOLO approach was chosen is because it can be useful in determining whether the additional sensory information afforded by haptic technology impacts the manner in which students understand more complex phenomena (Minogue & Jones, 2009, p. 1361). The reason why a haptic pathway was chosen to analyze is because we often use touch to discover the world around us and the sense of touch is a cognitive system that allows learners to help commit concepts to memory (Minogue & Jones, 2009, p. 1363).

To examine how haptic feedback influences student understanding of passive transport through a cell, research was conducted at a low income urban middle school in South Eastern USA with 80 student participants. Participants all completed a pre-test prior to being randomly separated into a control group or experimental group consisting of 40 students each. Members of the control group received only visual feedback while the experimental group received visual and haptic feedback as they completed the program (Minogue & Jones, 2009, p. 1364). Students in the experimental group interacted with a cellular environment to examine the differences between the molecules that can and cannot pass through a cell membrane. Since these students received visual and haptic feedback, they utilized a PHANToM desktop device that consists of a robot-like arm that simulates fingertip contact with virtual objects through a pen stylus (Minogue & Jones, 2009, p. 1365). The PHANToM device detects collision with virtual objects to simulate the sense of touch and allow the user to feel the forces of molecules as they pass through a cell membrane. Students in the control group completed the same procedure as the experimental group, however their haptic abilities were switched off and could not manipulate molecular motion or feel force feedback (Minogue & Jones, 2009, p. 1367).

The pre-test scores indicated that all students had either a Prestructural or Unistructual
surface level understanding about the cell membrane and selective permeability. Contrastingly, when the students completed a post-test after the intervention, there were more students in the experimental groups that received both visual and haptic feedback that reached a SOLO level of either Rational or Extended Abstract (Minogue & Jones, 2009, p. 1369). This indicates that with the addition of the haptic feedback, students were able to reach the highest SOLO level and utilize more critical thinking and analysis to go beyond a basic level of understanding. It also suggests that regardless of the addition of haptic feedback, the visual component that all students were exposed to allowed them to reach at least the third and fourth levels of SOLO taxonomy which is an increase from their pre-test on the content. It can be inferred that the addition of haptic technology combined with visual effects allowed the students to integrate the critical components of the concept, retain information and make connections between biological processes (Minogue & Jones, 2009, p. 1372).

**Manipulation and Visualization of Objects Augmented by Haptic Force Feedback**

The use of technology to deliver instruction to students has been an interest among educational professionals as well as their impact on student learning. Although these technologies are exciting and stimulating, there have been demonstrations of these simulations to weaken learning gains rather than strengthen them (Wiebe, Minogue, Jones, Cowley & Krebs, 2009, p. 667). Supporters of technological simulations state that virtual environments afford students the opportunity to explore phenomena that is otherwise not as tangible in their everyday environment due to cost, space, time and safety constrictions. Computer graphics have enhanced auditory and visual information, however many times these simulations lack a sensory component. Therefore, the evolution of haptic feedback technology offers learners the ability to extend their interactions and communicate with their environment beyond purely auditory and
visual means by providing realistic force feedback (Wiebe et al., 2009, p. 667).

This study involved 33 middle school students that attended a week-long science summer camp. The participants attended three different schools serving rural, urban and suburban students. The program used in this study presented students with information on first, second and third-class levers and afforded students with the opportunity to create their own lever (Wiebe et al., 2009, p. 669). In this randomized pretest-posttest control group design, the students were separated into an experimental group with 20 students and a control group with 13 students. The experimental group received bi-modal instruction, encountering visual and haptic feedback throughout the program. The control group received uni-modal instruction, receiving only visual feedback. For further analysis, a small subset of 17 students were exposed to eye tracking technology. Prior to the program exposure, the students took a pre-test to assess their understanding of levers (Wiebe et al., 2009, p. 670).

This program allowed students to interact with levers and make connections between the amount of load and the amount of force that is required to move the lever. The eye tracking data showed that including haptic feedback increased the amount of time students spent manipulating these elements compared to other components of the program. Although there was more time spent fixating on specific elements in the bi-modal group, there was no increase in performance because of it (Wiebe et al., 2009, p. 672). The results of the pre and post-tests, eye tracking and student performance during the intervention demonstrated that both groups were able to acquire the skill of determining which levers could take more force with or without haptic feedback. This finding suggests that haptics will not always overshadow purely visual information (Wiebe et al., 2009, p. 673). Therefore, if visual interpretations of a concept are available and suitable to learn content, haptic methods may not be necessary due to its high cost and frequent technical issues.
When examining the eye tracking data and analyzing videos, it was evident that haptic feedback caused students to spend more time manipulating and exploring an object. Although students are having a more intimate connection with the phenomena, there was nothing in the data that suggested that this significantly increased the students’ understanding. For haptic interfaces to contribute to increase learning, it must be timely, explicit and useful (Wiebe et al., 2009, p. 674). In this study, the haptic interface for this particular simulation was limited in those areas. Both groups relied heavily on the visual aspects of the intervention and it can be inferred that additional cognitive load of reacting to haptic stimuli may have impeded the learning of the experimental group (Wiebe et al., 2009, p. 674).

Based on these research findings, it is suggested that more labs are created to further the exploration of the positive and negative aspects of haptic simulations. Further research can be done to determine if implementing haptics truly support or impede learning by adding in frequent assessments throughout the activity. As more software is released and more programs are developed, instruction can be delivered to students of various ages and over a longer trial period to determine the long-term effects of haptic simulation compared to purely visual simulations (Wiebe et al., 2009, p. 674). Although this study suggests that the learning outcome when using haptic feedback does not outweigh the learning gains without haptic feedback does not mean that this is true of all virtual experiences. However, it is recommended that any additional research emphasizes the importance of whether the perceptual interactions with the specific simulations enhances the processing of information as well as the connection to the learned phenomena.

Models have been used during science instruction to make complex ideas seem simple and offer students a means to transfer their learning to new situations. For years, anatomy and physiology classes have used plastic models and organ dissections to increase active learning in
the classroom and improve student visualization of complex structures (Lombardi, Hicks, Thompson & Marbach, 2014, p. 80). The goal of this study was to implement pedagogical change from tangible anatomical structures to virtual structures to determine whether it caused an increase in active learning, learning gains, critical thinking and content retention (Lombardi et al., 2014, p. 81).

Twenty-Nine Anatomy and Physiology students consisting of 22 women and 7 men were separated into three test groups. Group one consisted of 13 students performing a real-life organ dissection, group two consisted of 8 students completing a virtual dissection and group three consisted of 8 students using a plastic model for dissection. All students completed a thirty-minute examination prior to their experimental treatment to measure their knowledge of anatomy and physiology of the heart. After each group’s dissection, the students completed a follow-up exam to determine learning gains (Lombardi et al., 2014, p. 81).

The students in the plastic model group received the highest overall score on the initial exam with a median score of 95.4%, which was significantly higher than the 77.3% median in the organ dissection group and the 70.4% median in the virtual dissection group. Students in the virtual dissection group received the lowest scored on each of the anatomical and physiological subsections of the initial exam (Lombardi et al., 2014, p. 82). The results of the follow-up exam also indicated that the overall scores of the students in the plastic model group scored higher than both the real-life and virtual organ dissection groups.

In conjunction with a follow-up exam, all students participated in a Likert-style survey where they expressed explanations for their survey responses. The survey results demonstrated that students in the real-life organ dissection group and plastic model group all either “agreed” or “strongly agreed” that science was fun, whereas only 62.5% of students in the virtual dissection
group believed that science was fun (Lombardi et al., 2014, p. 82). When viewed holistically, Lombardi et al. (2014) stated that the students in the real-life organ dissection group claimed that science encourages experimentation and promotes learning while the plastic model and virtual group believe that science is hands on and teaches one how the world words (p. 82). When surveying the participants about whether this dissection activity prepares them for their future careers, 77% of the real-life dissection students agreed or strongly agreed while 62.5% of participants from the plastic and virtual groups agreed or strongly agreed (Lombardi et al., 2014, p. 82). When all students were asked about their preference between real life organ dissection, plastic models or virtual models, real life organ dissection was requested more often. The students validated their reasoning for this decision by stating that the real-life model does not oversimplify the anatomy, physiology or visualization of the structures (Lombardi et al., 2014, p. 82).

Many scientific concepts require the visualization of complex structures. While virtual dissections offer a realistic approach to a model, many students believed that it pales in comparison to physically touching, manipulating and analyzing a real organ. While a virtual model may allow a student to visualize things like blood flow and the pathway of blood around the heart, the physical model maintained engagement and increased curiosity in a way that did not oversimplify the topic at hand (Lombardi et al., 2014, p. 83). Although the students in the plastic model group demonstrated a greater understanding of the heart’s structure and function, this does not indicate that virtual representations of biological structures should never be utilized. In this situation, a plastic model of the heart increased students’ ease of access to the internal heart structures without having to spend time manipulating the object. This in turn could have maximized their study time compared to the real-life and virtual organ dissection groups.
(Lombardi et al., 2014, p. 84). Although the plastic models have many benefits, they are less inquiry-based in their approach compared to real-life and virtual dissections. Both real-life and virtual dissections provide students with more opportunities to discover models in a complex manner that is realistic (Lombardi et al., 2014, p. 85).

It is suggested that certain aspects of the science curriculum, such as learning about the heart, are augmented with virtual dissections or real-life dissections to fully convey the workings of a living system (Lombardi et al., 2014, p. 85). Although this study revealed that a virtual heart dissection was unpopular among students and did not increase knowledge, it is important to note that this choice was up against a real-life organ dissection which has always been an interest to students. However, when taking cost into consideration virtual dissection is a viable option to deliver content knowledge about scientific concepts that are not as palpable (Lombardi et al., 2014, p. 85).

Science educational reform has been making a gradual shift towards the utilization and practice of experimentation that allows the students to be more independent and manipulative with their environment. Virtual Manipulative Experimentation (VME) involves the use of a virtual apparatus in an effort to increase student’s skills, attitudes and understanding of concepts (Zacharia & Olympiou, 2011, 317). Although virtual experimentation can enhance laboratory experiences, there have also been arguments against VME due to its lack of hands-on manipulation and ability to physically relate to their environment. The purpose of this study is to determine if it is manipulation rather than physicality that is imperative towards student learning through experimentation (Zacharia & Olympiou, 2011, 318).

PME refers to a physically manipulative learning environment that involves students physically touching and manipulating objects in the real world (Zacharia & Olympiou, 2011,
A key factor of PME is physicality, identified as actively touching concrete objects by tactual means to discover their characteristics. PME also requires manipulation, which is when the learner utilizes motor skills to interact with materials in a skillful way to construct knowledge. PME is fully executed when there is a meaningful exploration through physical touch and thoughtful manipulation of materials (Zacharia & Olympiou, 2011, 318). There has been an increasing interest in incorporating haptics in virtual learning environments to contribute to and mimic the physicality of student learning and reduce cognitive load (Zacharia & Olympiou, 2011, 318).

VME refers to an environment that is virtually manipulative by nature that allows students to virtually manipulate and interact with objects and apparatuses through haptic means to simulate physical experience. Instead of being used to complement PME, VME is starting to be utilized as a method to match PME. VME affords students with an active, hands-on, portable, safe, scaffolded and low error environment that can provide students with a deeper understanding of the material (Zacharia & Olympiou, 2011, 319). In this study researchers created four experimental groups, a group exposed to PME with physicality, a group exposed to VME with no physicality, a group exposed to both PME and VME and a group exposed to traditional instruction with the absence of both PME and VME (Zacharia & Olympiou, 2011, 322). The participants of this study included 234 undergraduate physics students, 66 males and 168 females, that all completed the same four modules explaining the concepts of heat and temperature. All students completed the same pre-test prior to the modules and and completed the same conceptual post-test at the end of the modules (Zacharia & Olympiou, 2011, 325).

The results of this study indicated that the use of PME, being exposed to physicality, and VME, being exposed to a virtual environment, used alone or in combination can enhance student
understanding equally. Additionally, using either PME or VME alone or combined enhances student understanding more than traditional instruction (Zacharia & Olympiou, 2011, 328). This rejects the belief that physicality alone is a requirement for physics learning and that in fact manipulation of the environment, whether physical or virtual, is more important. In regards to an environment that is partially physical and partially virtual, findings suggest that it is important that the essential variables and interactions are the same in both environments to aid success (Zacharia & Olympiou, 2011, 328). When students are learning in an environment that offers more possibilities compared to a traditional lab environment, they are able to surpass the typical every day experiences they have been learning and build upon their prior knowledge. Overall, through observations and quantitative analysis of the assessment scores, it is evident that a virtual learning environment provides the students with a unique experience that promotes understanding equally as well as an environment that is solely physically manipulative. Therefore, since switching the learning environment to one that is virtual allows for less preparation, more possibilities for manipulation and ease of portability at a relatively low cost, VME is appealing to teachers to deliver instruction and allow their students to experience an environment that is not typically tangible.

**Embodied Cognition and Physical Manipulation Through Haptics and Virtual Reality**

Individuals will often utilize their imagination or prior experiences to understand a physical system at work. However, if these individuals have not experienced or encountered certain phenomena they have nothing to ground their mental simulations (Han & Black, 2011, p. 2281). The idea of embodied cognition places emphasis on the importance of prior experiences to emphasize thought, knowledge and connections to the physical world. This theory can be applied to education to enhance student knowledge of abstract concepts. This study mainly
focuses on the importance of how interacting with multisensory simulations can offer the necessary cognitive grounds for learning physics concept at the elementary level (Han & Black, 2011, p. 2281).

There is a positive correlation between the physical manipulation of objects and the comprehension of abstract concepts. Haptic interactions involve manual communications with specific environments by exploring and extracting information from that environment. To determine if a haptic interface can be used to teach concepts of simple machines and forces, 220 fifth graders from eleven different classes and three different elementary schools from low socioeconomic backgrounds from the Bronx, New York participated (Han & Black, 2011, p. 2284). The goal of this study was to allow students to use haptic software to build their own representation in their mind about new material based on their experience (Han & Black, 2011, p. 2283).

The simulation used for this study involved a gear simulation that contained moving images in an Adobe Flash animation and responded to user input and programming (Han & Black, 2011, p. 2285). Over a two-week time-period, students first completed a pre-test on information about gears followed by the completion of three simulations that explained how gears work. Once the simulations were completed, students completed a post-test on the information learned in the simulation, viewed instructional videos about how common household items work via gear operation and completed a second post-test (Han & Black, 2011, p. 2286).

The first finding of this study demonstrated that force and kinesthetic haptic augmented simulations are more effective than non-haptic simulations in regards to providing students with a genuine perceptual experience. The haptic simulation offered the elementary school student participants the ability to construct multimodal models of machinery movement on their own
Students who used haptic simulations outperformed those who did not use haptic simulations, which could be correlated to the fact that haptic virtual reality offers a richer perceptual experience to students by using visual, auditory and haptic inputs (Han & Black, 2011, p. 2288). The second main finding revealed that although the activity utilized haptic simulations it was evident that the students benefitted the most from partaking in the simulations that were both kinesthetic and provided force feedback to provide a completely multimodal depiction of the content (Han & Black, 2011, p. 2288). The haptic simulations provided the students with the necessary means to access their prior knowledge or craft their own experience. When students are able to control their own memory, they are able to retrieve and envision the visual, auditory and haptic information and relate it to the content taught by their teachers. The students that did not partake in the haptic simulations were not able to utilize any cognitive grounding to build comprehension and link it to experience (Han & Black, 2011, p. 2289).

It is important that teachers properly utilize haptic and virtual simulations as an anchor that allows students to relate the content being learned to their prior experiences. Haptic simulations allow students to manipulate objects that they cannot normally encounter in their everyday lives. By allowing students to participate in these simulations it provides students with a visual, auditory and tangible method of learning information. Once students can make sense of multimodal representations, they are able to consistently refer back to these experiences to enhance future learning (Han & Black, 2011, p. 2289). Although it is evident that haptic simulations and emerging technologies can enhance learning, it is imperative that the perceptual stage of learning is activated to acquire more abstract knowledge (Han & Black, 2011, p. 2289).
One of the benefits of a virtual world in the classroom is that it allows students to experience natural phenomena in a tactile way that engages one’s sensory pathways. Although haptic experiences allow students to engage in a world that is not often tangible, there has been relatively little evidence to reveal any significant differences in cognitive gains between students receiving either haptic feedback or pure visual feedback (Schönborn, Bivall & Tibell, 2011, p. 2096). Therefore, one of the goals of this study was to explore the relationships between student interaction with haptic software that allows for the modeling of biomolecular binding (Schönborn, Bivall & Tibell, 2011, p. 2096). Biomolecular binding involves the specific orientation of a small molecule into a protein binding site. Students searched for this specific positioning of various molecules using 3D stereo graphics and a pen-like stylus to manipulate the molecules until they reached the correct binding site (Schönborn, Bivall & Tibell, 2011, p. 2097).

This research involved 20 postgraduate life science students consisting of 8 females and 12 males. Ten students interacted with haptic force feedback in the experimental group, and the other ten students interacted with no haptic force feedback in the control group. Before and after the students were exposed to the software, students engaged in responding to a written conceptual question outlining the process of a ligand binding to a protein molecule (Schönborn, Bivall & Tibell, 2011, p. 2098). The responses to this pre and post-test question served as the basis to measure any changes or increase in conceptual gains of biomolecular binding after they have engaged in the haptic model. Along with the written assessment item, student interactions in both the control and experimental group were tracked to measure the amount of time each student spent interacting with and manipulating the molecules (Schönborn, Bivall & Tibell, 2011, p. 2098).
One of the findings this study presented was that the haptics group spent less time interacting with the model and were able to determine binding positions more quickly compared to the non-haptics group, however there was no significant difference in accuracy (Schönborn, Bivall & Tibell, 2011, p. 2100). Also, students in the group receiving no haptic feedback positioned the molecules in closer differences to the surface of the protein molecule over a period compared to the haptics group. This has important implications regarding the way students use the no-haptics model to problem solve (Schönborn, Bivall & Tibell, 2011, p. 2101). One of the measures of engagement was the number of times students activated switches in the model when docking the protein molecules at their binding site. Students with the highest engagement in representational switches were from the no-haptics group. Students with the least representational switches were from the haptics group. It was concluded that those who showed higher learning gains during the study engaged with the representational switches less times, therefore those engaging with the haptic model experienced more learning gains than the no-haptics model (Schönborn, Bivall & Tibell, 2011, p. 2101).

Overall, students in the haptics group were more precise with their trajectory paths when locating and binding molecules together compared to the no-haptics group. Although the haptics group received touch feedback to guide their understanding, it is also hypothesized that their engagement with the multimedia model was a motivating factor that allowed for them to manipulate the object correctly (Schönborn, Bivall & Tibell, 2011, p. 2102). In conjunction with the positive correlation between haptics and student interaction, the students exposed to haptic feedback demonstrated higher cognitive gains based on their low amount of grip changes and representational switches. A possible reason for an increased cognitive capacity during the intervention could be due to the low demand placed on the visual pathway alone. This permitted
the students to essentially “free up space” to allow themselves to link new mental representations to pre-existing knowledge (Schönborn, Bivall & Tibell, 2011, p. 2103).

The results of this study offer implications of cognitive theory for explaining learning with haptic models. It is evident that a 3D visual display with haptic feedback could offer the students an embodied experience to aid their understanding of phenomena that is submicroscopic and intangible (Schönborn, Bivall & Tibell, 2011, p. 2103). Many theories regarding modality specificity do not explain the relationship between limited capacity and the “constructivist nature of human cognition” (Schönborn, Bivall & Tibell, 2011, p. 2103). Determining the impact individual preferences, attitudes and prior experiences has on the construction of knowledge would be valuable to apply to investigating the benefits of multimodal platforms (Schönborn, Bivall & Tibell, 2011, p. 2103).

**Construction of Knowledge Through Prior and Individualized Experience**

The utilization of haptics, or simulated touch, presents a breakthrough in delivering instruction to students. Although haptics presents a new method of sensory instruction, there is limited literature supporting the positive aspects of haptic technology in comparison to research that supports simulations with solely visual and audio feedback (Minogue & Borland, 2016, p. 187). A shared sentiment among literature supporting haptic feedback states that it induces knowledge through personal experiences that normally would not occur (Minogue & Borland, 2016, p. 188).

Although the concept of buoyancy is one that is easily accessible to students and can be explained through every day experiences, is it still a difficult concept for students to explain and construct (Minogue & Borland, 2016, p. 188). A culmination of studies and assessments of individuals in prior research has demonstrated that students often have misconceptions about
buoyancy, which indicates that that learners often focus on one specific dimension of the phenomenon and therefore lose sight of the true understanding of sinking and floating. This study serves to discover whether multimodal mental representations serve as “cognitive grounding” for understanding intangible phenomena (Minogue & Borland, 2016, p. 189).

This study uses a haptic device called The Falcon, which is intended to better assist learners reason and construct knowledge of abstract ideas concerning buoyancy. Minogue and Borland (2016) posed the question “How does haptic feedback influence users’ understandings of buoyancy” (p. 192). The participants in this study consisted of 40 undergraduate education majors and engaged in series of exercises to guide their exploration of various factors that could affect an object’s ability to sink or float. Out of the 40 participants, 22 students were exposed to haptic feedback while 18 students were not exposed to haptic feedback. Students were provided with no audio feedback, directions or text in the simulation. Both groups experienced identical core simulations however one group did not receive any force feedback (Minogue & Borland, 2016, p. 192). Prior to completing the simulation, students completed a demographics survey, a prompt eliciting a response about why things sink and float and completed a four-question close-ended questionnaire. Upon completion of the simulation, students completed the same prompt about why things sink and float as a post assessment (Minogue & Borland, 2016, p. 192).

When analyzing the pre and post assessment prompts, there was no significant gain in scores before and after haptic exposure. Typically, students are presented with scientific ideas through visual methods only (Minogue & Borland, 2016, p. 195). A common finding throughout the analysis of the data collection tools suggests that visual stimuli is sufficient in increasing one’s knowledge on its own. The study demonstrated that visual analysis was exhausted long before the student was able to engage in haptic exploration. Therefore, it is an be inferred that
perceptual information delivered through haptic means was never utilized to its fullest extent by the learners when completing their paper-based assessment of their knowledge gains (Minogue & Borland, 2016, p. 196). Future research can include more performance-based tests that are targeted towards perceptual skills gained through haptic technology rather than offering an assessment through traditional means. This can serve to emphasize the differences between the learners exposed to haptic methods and those that were not.

One of the main differences between the haptic and the non-haptic groups was their use of vocabulary. It was observed that students exposed to haptic feedback utilized vocabulary related to the concept of buoyancy more frequently such as push, force, net force, buoyant force, gravity and pushing (Minogue & Borland, 2016, p. 197). The haptic users also made better sense of the idea of water displacement and were able to make connections between variables. Therefore, those receiving haptic feedback were able to overcome certain shortcomings such as being unable to identify the factors that affect buoyancy or understanding the importance of displaced volume of a liquid when determining buoyant force (Minogue & Borland, 2016, p. 197).

There is no doubt that haptic technology impacts the way in which learners perceive, engage in and select information for further processing. However, it is still unclear whether it is significantly better than visual stimuli when understanding the physical world (Minogue & Borland, 2016, p. 197). This aspect of technology is young and requires more evidence to gain insight into individual perception, processing, storing and sense making of these multimodal learning environments. This early evidence is worth exploring further to develop a theory that studies language-mediated haptic cognition (Minogue & Borland, 2016, p. 198). With vocabulary usage being the main difference between the two groups, it is evident that haptic
feedback did have some effect on individual sensory information after all. Since written and spoken language is a crucial tool for narrowing the gap between higher and lower mental functions, further research can be carried out to determine whether haptic technology can allow students to construct and communicate concepts better than visual representation alone (Minogue & Borland, 2016, p. 198). Expanding this study to include more test subjects or various learning abilities can lead to a more concrete generalization of the effects of haptic feedback.

Compared to other subjects, there has been an increasingly low interest in science among children due to lack of motivation and inability to connect it to the real world. In an effort to connect abstract scientific concepts with the real world, this study sought out to bridge the gap between virtual content and the real world with augmented reality (Laine, Nygren, Dirin & Suk, 2016, p. 507). The technology used in this study was an Android based Science Spots augmented reality (AR) platform that educated students about scientific concepts through story-driven learning games (Laine et al., 2016, p. 508). Augmented reality is a technology that utilizes 3D models, animations and other annotations placed in a real-world view. The technology is implemented using cameras, interactive pens, machine vision algorithms and content rendering. The addition of haptic feedback allows students to improve spatial skills, hand-eye coordination and have physical contact with a real-world environment (Laine et al., 2016, p. 509).

The goal of Science Spots AR is to combine the benefits of storytelling, gaming, context-awareness and augmented reality to increase student comprehension of difficult scientific concepts in a way that is enjoyable and interactive (Laine et al., 2016, p. 511). To measure the conceptual practicability of Science Spots AR, a test group of sixty-one 5th graders were used composed of 52% male students and 48% female students (Laine et al., 2016, p. 519). First, the students were initially surveyed based on their demographics, mobile phone usage and gaming
experience and their attitude towards science and math. After the initial survey, students engaged in the gameplay experience of a program in Science Spots called Leometry, which educates students about geometric shapes in nature (Laine et al., 2016, p. 521). Along with surveying their likes and dislikes as well as motivational aspects of the game, eight students were interviewed to gauge an idea about their perceptions of the module as well as its effectiveness (Laine et al., 2016, p. 521).

It was observed that challenge, competition and social gameplay were factors of motivation for many students. The students were observed to be eager to solve problems so they could proceed to the next game level and were often collaborating amongst themselves. It was also evident by the facial expressions of students that they went through periods of being very concentrative, very frustrated and also very accomplished with their tasks (Laine et al., 2016, p. 523). Based on the survey results of student perceptions of the intervention, 79% of the students agreed that Leometry was an interesting learning tool, however there were some students that still disagreed that using this type of technology was an effective learning method (Laine et al., 2016, p. 525). Over 80% of students agreed that this was a good way to learn new topics, it was more exciting than normal class and it changed the students’ attitudes toward the subject in a positive way (Laine et al., 2016, p. 525).

The implementation of augmented reality and the interaction with haptic and touch feedback, which uses a corresponding wand and smart device, students were able to receive immediate feedback on their efforts to guide their progress and collaborate with their peers throughout the process (Laine et al., 2016, p. 526). When using these programs in a class setting, it is important that students become familiar with the technology prior to interacting with it in the lesson to minimize errors and increase precision. Although this technology can suit the needs of
many learners by increasing the tactile interaction with often intangible phenomena, games should contain multiple levels of difficulty to accommodate the various skill levels the students possess (Laine et al., 2016, p. 527). Currently, many of these platforms do not offer many pedagogical objectives. Aligning the simulations to content curriculum could enhance the effectiveness of the how the material is delivered through virtual means. The Science Spots AR platform is compared to a physical playground as it allows students to use multiple senses to learn about the world around them. By engaging students in different ways that adhere to their senses, it opens the door for dynamic learning opportunities in a playful manner (Laine et al., 2016, p. 528).

To provide students with a unique learning experience, it is suggested that physical and virtual labs are combined to deliver scientific content and connect ideas. The use of physical labs alone are often insufficient in allowing students to understand difficult scientific concepts since they do not provide the visualization of phenomena (Chao, Chiu, DeJargher & Pan, 2016, p .16). Including visualizations and simulations of scientific phenomena can increase student understanding, especially at the molecular level. Learning with virtual and augmented reality, haptic technology and tangible user interfaces provide a multimodal learning experience for users and can also increase their spatial reasoning skills (Chao et al., 2016, p. 17). This study uses a mixed-reality interface called The Frame, which allows students to physically manipulate and interact with simulations in ways that cause an impact in their virtual world (Chao et al., 2016, p. 17).

An important aspect of learning is to build off students’ everyday experiences. Failure to connect new knowledge to existing knowledge often results in incoherent understanding of scientific concepts (Chao et al., 2016, p. 17). A complex and fundamental understanding of
science lies within the ability to connect observable phenomena to certain behaviors at the molecular level. Providing students with opportunities to experience an environment that is both physical and virtual can allow them to organize their ideas, discover conflicts between prior knowledge and new ideas and fine tune their understanding of the concepts (Chao et al., 2016, p. 17). An effective virtual experience also involves the use of haptic technology, which allows the user to physically manipulate virtual objects while feeling force and kinesthetic feedback from a computer (Chao et al., 2016, p. 18).

The Frame technology used in this study uses a computer simulation and fast-response sensors that consistently collect and transmit data to the simulation in order to change its parameters, therefore the students are essentially controlling the virtual world. However, instead of using haptic devices such as a glove, pen or joystick, The Frame uses actual physical objects to augment the student’s experiences. For example, students will increase the temperature of the simulation’s environment by using a hair dryer rather than a button on the screen (Chao et al., 2016, p. 19). More specifically, this study is using The Frame to allow students to understand gas laws by literally connecting their physical environment to their virtual environment and build upon their existing ideas (Chao et al., 2016, p. 20).

The participants for this study included thirty chemistry students, 50.8% males and 49.2% females, from two different classes in 10th and 11th grade. One class of 16 students was assigned to the group that would interact with The Frame, and the other class of 14 students were assigned to the traditional group (Chao et al., 2016, p. 21). The Frame group used the software and a paper-based guide to investigate molecular behavior, temperature and pressure in gases based on Boyles’ Law and Charles’ Law (Chao et al., 2016, p. 21). The traditional group investigated Boyles’ Law using a physical lab with materials consisting of a syringe, gas
pressure sensor, computer and a computer interface to collect data (Chao et al., 2016, p. 22). To compare the understanding between both groups, an assessment was distributed to the students consisting of nine questions that required students to make predictions or provide explanations for observed phenomena. The responses to these questions provided insight to the students’ ability to make connections between concepts at a microscopic and macroscopic level (Chao et al., 2016, p. 23).

Based on the overall student performance, there was not a statistically significant advantage of using The Frame over traditional labs. However, The Frame did aid students in learning particular concepts that link the physical and molecular properties of gas better than traditional instruction (Chao et al., 2016, p. 27). For example, when students touch a hot jar with the temperature sensor tip, there is an immediate visualization that appears on the screen that demonstrates the fast and frequent collisions of the gas molecules. Therefore, the increased performance of The Frame group on particular assessment items could be due to the exposure to real-time connections (Chao et al., 2016, p. 27). The Frame also required significantly less set up compared to the traditional lab, which allowed the students in The Frame group to investigate multiple gas laws whereas the traditional group only had enough time to investigate one law. Students in The Frame group used the molecular visualizations to create explanations for molecular phenomena, which increased conceptual learning compared to the traditional group, who relied solely on teacher lead descriptions (Chao et al., 2016, p. 28).

This study further supports the argument that states that interactions with physical and virtual environments offers valuable ways to comprehend scientific concepts. Simultaneous connection between both physical and virtual environments can help students make more consistent connections between macro and microscopic phenomena (Chao et al., 2016, p. 28).
Additionally, the haptic controls and haptic feedback authenticates the user’s experience in ways that are not tangible in a setting that is solely physical. It is suggested that educators use sensor-augmented virtual labs to hone in on specific learning objectives that require a more complex understanding (Chao et al., 2016, p. 29).

Science and technology play a key role in today’s society, therefore it is important for students to understand the importance of the science to gain an understanding about the world and how to improve the quality of life. Science is the most difficult, time consuming and least interesting subject to older students, and the use of high speed simulations with e-learning environments and haptic devices can increase the engagement and knowledge of students (Christodoulou, Garyfallidou, Ioannidis & Papatheodorou, 2008, p. 4).

The utilization of computers as a tool for teaching science has many benefits. Not only can it target more specific portions of the curriculum that may be difficult to replicate with classroom materials, but it can promote student independence and allow for students with various abilities to self-pace their learning (Christodoulou et al., 2008, p. 5). Typically, most computer programs and interfaces provide users with visual and auditory information through a screen and data input communication made by a keyboard or a mouse. More recently, the usage of haptic devices has increased. Haptic interfaces allow users to act on their environment by receiving tactile and kinesthetic simulation. Students that are haptic or kinesthetic learners can now interact with their virtual environment through the sense of touch (Christodoulou et al., 2008, p. 5). To transmit these sensory perceptions to the user, special input and output devices such as joysticks, pens or gloves are used and controlled by the user’s motions and the computer. The user can receive feedback from the computer application in the form of a sensation on their body (Christodoulou et al., 2008, p. 8).
One of the goals of this research was to promote student independence through the idea of constructivism. To do this, a pre-test was given to the 163 student participants to identify what they understood prior to the intervention, 64 students were primary school students, 74 were lower secondary school students and 25 were upper secondary school students. After the pre-test, students engaged in a haptic experience on Newtonian Physics and the Solar System and Virtual Gears and then completed a post-test questionnaire (Christodoulou et al., 2008, p. 10). The results of the pre-test suggested that students had many misconceptions when explaining the shapes of planets and their corresponding mass, and the older students in this study severely lacked skills in explaining the concept more so compared to the students in lower grades (Christodoulou et al., 2008, p. 13). As for gears, most students were able to make a logical prediction about what will happen when looking at a diagram of three gears (Christodoulou et al., 2008, p. 14). During the post-test, the students’ ability to answer questions related to gravity, mass and size of planets significantly increased after exposure to haptic software (Christodoulou et al., 2008, p. 15).

Based on the results of the questionnaire, students were excited and motivated by the haptic experience and would like to repeat the experience in the future. Students also reported that they would like to see the haptic software extend its abilities even further in future experiences (Christodoulou et al., 2008, p. 18). During the intervention, students were observed to be peer-teaching throughout the activity and expressed interest, knowledge gains and enthusiasm while using the software. Although using haptic software was a large success for students from young primary age to upper secondary age, some students did express in the survey that although haptic devices delivered a touch sensation, it was not something that felt real. Students also noted that they struggled at times with the way that the haptic device fit on their hand which impeded their
efforts in smoothly executing the correct motions needed to complete the simulation
(Christodoulou et al., 2008, p. 18).

Although much research surrounding haptic feedback is still preliminary in comparison
to other technological efforts in the classroom, the usage of such technology can promote critical
thinking, self-teaching, peer collaboration and differentiation in the classroom.

**How Haptics Can Benefit Diverse Learners**

Virtual reality has demonstrated many positive outcomes in the education world and has
enhanced learning in many ways. To determine the impact virtual reality has on student learning,
this study utilized a 3D virtual reality English language learning online platform to examine
student learning effectiveness based on Bloom’s cognitive complexity level (Chen, 2016, p.
637). Virtual learning environments provide students with the ability to create, share, and
visualize authentic content and create meaning from what they are learning. Virtual learning is
deemed very helpful for students learning a new language as it offers students opportunities to
interact in the targeted language. It also provides these students with virtual field trips, tours and
role play to enhance their experience and collaborate with others in their goal language. Virtual
reality is more experiential than classroom experiences and allows the students to become
immersed in the simulation so they can expand on concepts that cannot be taught in class (Chen,
2016, p. 637).

Allowing students to construct their own knowledge through participation, exploration
and interaction is a key factor of education. Since virtual reality is characterized by the ideas of
immersion, interaction and involvement, a virtual learning environment would provide students
with a form of reality that can let them explore a new environment through engaging means
(Chen, 2016, p. 638). The exploration of virtual learning environments with language learners
have demonstrated that students often engage in higher order thinking skills of Blooms Taxonomy and have expanded on the skills such as evaluating, discovering, interpreting and problem-solving (Chen, 2016, p. 638). This study aims to evaluate whether English learning virtual worlds can enhance student linguistic abilities and higher order thinking using Bloom’s learning objectives (Chen, 2016, p. 639). The participants included 448 students, 53.6% males and 46.4% females, taking a first year Basic English class at a university in Taiwan. The students were required to take a pre-test prior to the semester long intervention, and a post-test after the intervention to determine if there was any significant increase in cognitive skills. (Chen, 2016, p. 639). During the intervention students completed six modules throughout the semester, each focusing on a different unit and task to accomplish (Chen, 2016, p. 638).

When comparing the results from the pre and post-tests, there was a statistically significant difference in the values. This suggests that students have made valuable progress after interacting with the virtual world. One specific finding is that students demonstrated an increase in their phonological abilities. They were able to recognize words from listening and differentiate the syllables and the various sounds of words from the virtual world (Chen, 2016, p. 640). Although they were able to distinguish the sounds of words, a few students still struggled with the various heavy and light stresses placed on words. This implies that it would be beneficial to further emphasize aiding students in developing more of the phonological abilities using virtual learning environments (Chen, 2016, p. 640). Although differentiating between the stresses on words, students displayed a large growth in their vocabulary retention, acquisition and usage (Chen, 2016, p. 641).

Along with phonological growth, students displayed morphological growth in terms of Bloom’s levels of applying, understanding and analyzing. This suggests that students did not
have much difficulty with differentiating and making inferences and were able to choose correct answers based on their knowledge of root words, parts of speech, intonation and implied contexts learning in the virtual learning environment (Chen, 2016, p. 642). The pre and post-test comparisons also demonstrated that students improved upon their ability to write coherent sentences and could also craft new sentences using the language they were learning (Chen, 2016, p. 642).

The results of the study indicate that the virtual learning environment allowed students to immerse themselves in an environment that positively affected their cognitive development. The virtual learning environment was one that was easy to use, realistic and gave the students a sense of control and ownership since they were able to create an avatar that they would explore the virtual world with (Chen, 2016, p. 643). Throughout the virtual experience, it was observed and noted in the pre-test and post-test scores that the full range of Bloom’s Taxonomy of cognitive learning was demonstrated in various linguistic items, which allowed students to acquire knowledge through higher levels of thinking (Chen, 2016, p. 644).

In addition to increased cognitive development, teachers found that the virtual reality solved problems that involved learning new words. For language learners, it is best to learn words in corresponding context. However, if students cannot experience it or encounter these conversational contexts this effort can fall short. The virtual world helped students learn these new words by listening to them in meaningful texts that were verbal, haptic and tactile (Chen, 2016, p. 644). This provided students with experiential feedback that triggered many of their senses to help them retain the new vocabulary. It would be beneficial to target other issues that language learns have and see if they can be solved through the interaction with virtual environments to enhance their learning outcomes.
The goal of virtual reality learning environments is to create a realistic environment for students that aid in their learning process. Virtual reality technology has been a constant in our daily lives for the past few decades and has become a staple in many students’ lives. Combining virtual reality with educational instruction can help students relate to what their learning in ways that they are familiar with. To increase realism in the classroom when using virtual technology, haptic features are added, which provides the virtual learning environment with an increased sensory and tactile experience. This enhances human interaction with machines and brings even micro-nano and intangible features to a realistic perspective (Ucar, Ustunel, Civelek & Umut, 2016, p. 540).

Haptic is defined as sense of touch and mainly refers to usage of the hands and receptors on the skin when sensing touch. With haptic technology comes haptic feedback, which is a force feedback system that refers to zones where force of a haptic sense is perceived by receptors found in muscles and tendons. Haptic feedback can be tactile, involving the feedback of signals like pressure, strain and heat through the skin, or it can be force feedback which affects the zones where the force that is applied from the virtual environment to the user by pushing back (Ucar et al., 2016, p. 541).

The goal of this study is to determine how haptic technology impacts the learning process of gifted students’ attitudes towards chemistry and to see if it can provide permanent learning. The participants of this study involved 52 gifted students consisting of 18 females and 34 males. The students were randomly separated into two groups, one being educated through haptic application and force feedback and the other group being educated through traditional teaching methods. Both groups learned about the same concepts involving chemical bonds and the gravitational attraction between elements (Ucar et al., 2016, p. 545). Based on the results, the
utilization of force feedback and haptic applications in virtual reality environments had more positive effects on student attitudes towards chemistry than that of the traditional environment. (Ucar et al., 2016, p. 545).

Once the students received instruction on chemical bonds, they engaged in a survey that prompted them to indicate their perceptions toward force feedback haptic applications in virtual reality environments. Students in the control group receiving traditional instruction believe that force feedback haptic applications in virtual reality environments would not provide them with the same standards of learning that traditional instruction does since it forces students to work independently of the teacher. The students in the control group believe that instruction should come from a teacher and not from a virtual machine. However, the students in the experimental group believed that quality results can be obtained from force feedback haptic applications in virtual reality environments and that it should be more commonly used in the classroom when learning complex scientific concepts that require excess visualization (Ucar et al., 2016, p. 546).

Education is often finding ways to aid students with special needs, disabilities or lower performing students. Gifted students are often perceived as students that do not require aid, however they often require more simulation than their peers to remain engaged and maintain their interest (Ucar et al., 2016, p. 544). Although gifted students may not typically struggle when learning a difficult scientific concept, force feedback haptic applications in virtual reality environments about chemical bonds increased knowledge and interest in the subject for the students more than the gifted students in the traditional instruction group. Providing students with force feedback haptic applications allows them to experience new learning opportunities and familiarize themselves with concepts are not often palpable (Ucar et al., 2016, p. 546). Teachers are constantly receiving students with a wide range of needs, therefore the use of haptic
technology and virtual reality can help teachers supplement their traditional learning styles to fulfil these changing needs (Ucar et al., 2016, p. 546).
Chapter Three: zSpace Virtual Lab Activities

What is zSpace?

zSpace is a computer software that offers a unique interactive, augmented and virtual reality experience that allows users to explore phenomena that may be relatively unfamiliar. The difference between zSpace computers and regular computers is that zSpace offers users three sensory characteristics to enhance the learning experience: Enhanced depth perception, the ability to look around and manipulate the objects 360 degrees, and kinesthetic realism.

To achieve this mobility and realism on the zSpace computer, students will use three zSpace accessories:

1. Driver Glasses
2. Passenger Glasses
3. zSpace Pen

### Driver Glasses
- Thin frames
- Have sensors on the side that track movement on zSpace computer
- Worn by the user that is holding and operating the zSpace pen

### Passenger Glasses
- Generic 3D glasses
- Does not have sensors
- Worn by user accompanying the “driver”
- Will be able to see all 3D aspects of the simulation that the driver sees

### zSpace Pen
- Click circle button to grab objects
- Click and hold circle button to pull objects out of the screen
- Click the right button and left button for various other commands depending on zSpace application
- Haptic feedback is received through pen
The zSpace system has tracking built into the monitor and syncs with the tracking in the driver glasses. Users can tilt their heads to look around a scene, look around an object or maneuver their heads to pull objects out of the screen. If users become dizzy due to the sensory experience, they can switch glasses with their partner and utilize the passenger glasses instead. The pen is used in conjunction with the driver glasses only and has the comfort and feel as a normal pen. This offers users a familiar interaction with the device and allows them to learn how to use it quickly. The system also offers haptic feedback to the user, which allows students to receive touch sensory feedback regarding their actions when using the software.

zSpace offers twenty different applications through the system. Each software is targeted to educate users on a variety of topics while prompting users to utilize skills such as analysis, measurements, engineering, developing models, testing ideas, manipulation and critical thinking. The four zSpace software that will be used in this series of lab assignments are below:

- **VIVED Science** is a comprehensive package of detailed interactive dissection experiences focused on learning and exploring Human Anatomy, Botany, Zoology, Earth Science, Microbiology, and more! (zSpace Laptop and All-in-One)

- **zSpace Studio** is a rich model exploration and presentation tool that allows students to compare, dissect, analyze, measure, annotate thousands of 3D models from the zSpace Model Gallery. (zSpace Laptop and All-in-One)

- **Newton’s Park** allows students to run or create their own experiments to deepen their knowledge of Newtonian Mechanics. Students can build simulations while interacting with data. (zSpace Laptop and All-in-One)

- **Curie’s Elements** allows students to explore a periodic table with Bohr and atomic models for each element. Students can also build elements by adding protons, neutrons, and electrons. (zSpace Laptop and All-in-One)

[https://zspace.com/apps/](https://zspace.com/apps/)
# zSpace Lab #1: Plant Cell vs. Animal Cell

<table>
<thead>
<tr>
<th>zSpace Application</th>
<th>VIVED Science: Animal (Human) Cell and Plant Cell Structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Title</td>
<td>Plant Cell vs. Animal Cell Structure</td>
</tr>
<tr>
<td>Course</td>
<td>Living Environment (8th Grade/9th Grade Students)</td>
</tr>
<tr>
<td>Unit/Topic</td>
<td>Cells/Organelles</td>
</tr>
<tr>
<td>Time</td>
<td>60 Minutes</td>
</tr>
</tbody>
</table>

## NYS/NGSS Standards

<table>
<thead>
<tr>
<th>NYS Living Environment Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2f Cells have particular structures that perform specific jobs. These structures perform the actual work of the cell. Just as systems are coordinated and work together, cell parts must also be coordinated and work together.</td>
</tr>
<tr>
<td>1.2i Inside the cell a variety of specialized structures, formed from many different molecules, carry out the transport of materials (cytoplasm), extraction of energy from nutrients (mitochondria), protein building (ribosomes), waste disposal (cell membrane), storage (vacuole), and information storage (nucleus).</td>
</tr>
<tr>
<td>1.3a The structures present in some single-celled organisms act in a manner similar to the tissues and systems found in multicellular organisms, thus enabling them to perform all of the life processes needed to maintain homeostasis.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NGSS Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS-LS1-2</td>
</tr>
</tbody>
</table>

## Rationale & Introduction

The lab Plant Cell vs. Animal Cell allows students to observe and experience the organelles of plant and animal cells in a 3D environment that is more exciting than using diagrams or compound microscopes with limited magnification. The lab provides students with the opportunity to visualize a fundamental scientific concept that traditional physical labs that utilize diagrams or a microscope cannot. The Plant vs. Animal Cell lab allows students to manipulate organelles by removing them from the cell, seeing their internal and external structures and hypothesize why they are structured in a certain way in relation to their function. Students will also create a connection to the cellular environment by making connections between organelles and their organs, which is something familiar to them.

## Benefits of Virtual Reality/Haptics

This lab can be used to pre-teach, teach or re-teach concepts about cellular organelles. The benefits of the virtual component is that it is more manipulative and experiential compared to traditional physical labs. Students can observe cells in the classroom under a microscope, however they are typically limited to seeing only the cell membrane, cell wall, nucleus and chloroplasts in plant and animal cells. The Plant vs. Animal Cell lab surpasses these limitations by allowing students to see the structure of all other organelles. The haptic component of this lab provides students with a sense of touch feedback to alert them when they are placing organelles in the correct locations of the cell when they construct their own cell or put one back together.

## Recommendations for Classroom Use

Although this lab can be used to pre-teach, teach or re-teach concepts regarding plant and animal cells, it is best used as a method of pre-teaching to assist students with independent learning and knowledge construction. Whether or not students have little to no knowledge about the cellular structures and organelles, incorporating this lesson into the classroom can introduce students to cellular organelles and how they are structured. Understanding and visualizing their structure as well as understanding which organelles are found in specific cell types, can assist students relate to each organelle’s functions, which they can learn in class. Students should guide themselves through this lab by following explicit laboratory instructions using a guided lab. With an 8th grade population, this lab would be most successful with checkpoint questions throughout the lab so the teacher can formatively assess and monitor student progress. Students should also work in pairs so neither student becomes too dizzy from overstimulation or from the 3D sensor glasses.
How to Open the Program:

1. Open “VIVED Science” from the desktop
2. Click “Open Session
3. Open the Animal (Human) Cell Structures session
Part 1: Animal (Human) Cell Structure

This portion of the lab you will explore an animal cell and its organelles. Place a “✔️” on each available next to each step below to ensure you are following the directions properly. Answer any questions that follow.

**Slide 1:** All living things are made up of cells, the basic unit of life. Let's take a closer look at an animal (or human) cell.

**Step 2:** Use the pen to point at Slide 2 (upper left hand corner)

**Step 3:** Using the white circular button on the pen click on Slide 2

**Slide 2:**

**Step 4:** First, notice the shape of the animal cell

✔️ How would you describe its shape? __________________________________________________________

**Step 5:** Using the white circular button on the pen click on Slide 3

**Slide 3:**

**Step 6:** Use the pen to point at the cell
✓ What is the name of the outer covering of the cell?
__________________________________________________________________________
✓ How would you describe it? Is it thick or thin? ________________________________

Step 6: _____ Using the pen click on the outer covering and remove it to see what’s inside.

Step 7: _____ Complete the boxes below.

Structure: Plasma Membrane (cell membrane)

<table>
<thead>
<tr>
<th>Draw an arrow pointing to the cell membrane</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Arrow to the cell membrane" /></td>
<td></td>
</tr>
</tbody>
</table>
Step 8: Using the pen click on Slide 4

Slide 4:

✓ Underneath the outer covering, we can see a jelly-like material that holds the cell's organelles.

✓ What is the name of this jelly-like substance? ___________________________

Step 9: Using the pen click on the top of the cell and move it to the side. Repeat this for the bottom of the cell.
**Step 10:** ____ Using the pen click on Slide 5

**Slide 5:**

**Step 11:** ____ We now have a clear view of the organelles inside an animal cell. Take apart the nucleus (5 parts total) to see what's inside.
Step 12: ____ Complete the boxes below.

**Structure: Nucleus**

<table>
<thead>
<tr>
<th>Draw an arrow pointing to the nucleus</th>
<th>Function</th>
</tr>
</thead>
</table>

Step 13: ____ Using the pen pull out the Rough ER, Smooth ER, and Golgi Body. Observe them.

Step 14: ____ Using the pen click on Slide 8 (NOT SIX!)
Step 15: ____ Using the pen, remove the top layer of any of the mitochondria.

Step 16: ____ Using the pen, rotate the mitochondria to see what is inside.

Step 17: ____ Complete the boxes below.

<table>
<thead>
<tr>
<th>Structure: Mitochondria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw the inside of the mitochondria</td>
</tr>
</tbody>
</table>
**Step 18:** Using the pen click on Slide 9

**Slide 9:**

**Step 19:** Remove the top of the vacuole to see inside.

✓ How would you describe them? Are they large or small? ____________________________________________
✓ Zoom out if needed. How many vacuoles do you see? ________________

Step 20: ____ Using the pen click on Slide 10

Slide 10:

Step 21: ____ Using the pen put the cell back together!

** STOP! GET YOUR WORK CHECKED! **
Part 2: Plant Cell Structure
This portion of the lab you will explore a plant cell and its organelles. Place a “✔” on each available “_____” next to each step below to ensure you are following the directions properly. Answer any questions that follow.

How to Open the Program:

1. From the animal cell screen, click on the house (top right corner)
2. Scroll down until you find Plant Cell Structures session
3. Complete the Plant Cells worksheet as you progress through the session

Slide 1: All living things are made up of cells, the basic unit of life. Let's take a closer look at a plant cell.

   Step 1: _____ Pick up the Z Space pen
   Step 2: _____ Use the pen to point at Slide 2 (upper left hand corner)
   Step 3: _____ Using the white circular button on the pen click on Slide 2
Slide 2:
Step 4: ___ First, let’s analyze the shape of a plant cell. Remove all the adjoining plant cells and their parts to observe the center cell alone.

✓ How would you describe its shape? ____________________________________________

Step 5: ___ Using the white circular button on the pen click on Slide 3

Slide 3:
Step 6: ___ Use the pen to point at the cell

✓ What is the name of the outer covering of the plant cell? _________________________

✓ Explain why you think this structure has pores ________________________________
Step 7: ____ Complete the boxes below.

**Structure: Cell Wall**

<table>
<thead>
<tr>
<th>Describe (in words) the color and shape of the cell wall:</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Step 8: ____ Using the white circular button on the pen click on Slide 4

**Slide 4:**

Step 9: ____ Using the pen click on top of the cell membrane and remove it. Repeat for the bottom.

Step 10: ____ Complete the boxes below.

**Structure: Cell Wall & Cell Membrane**

<table>
<thead>
<tr>
<th>Label (using arrows) the cell membrane and the cell wall</th>
<th>Function of the cell membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Step 11: ____ Using the pen click on Slide 5

Slide 5:

✓ Underneath the outer covering, we can see a jelly-like material that holds the cell's organelles.

✓ What is the name of this jelly-like substance? ___________________________

Step 12: ____ Using the pen click on the top of the cell and move it to the side. Repeat this for the bottom of the cell.
Step 13: ____ Using the pen click on Slide 6

Slide 6:

Step 14: ____ We now have a clear view of the organelles inside a plant cell. Take apart the nucleus (5 parts total) to see what's inside.

Step 15: ____ Complete the boxes below.

<table>
<thead>
<tr>
<th>Structure: Nucleus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Draw and label the nucleus</strong></td>
</tr>
<tr>
<td><strong>Function</strong></td>
</tr>
</tbody>
</table>

Step 16: ____ Using the pen pull out the Rough ER, Smooth ER, and Golgi Body. Rotate them around to observe their characteristics.
Step 17: ____ Using the pen click on Slide 9 (NOT SEVEN!)

Slide 9 (NOT 7 OR 8):

Step 18: ____ Remove the top of the vacuole to see inside.

✓ How would you describe it? Is it large or small? __________________________

✓ How many vacuoles do you see? __________________________

✓ How is the plant cell vacuole different from the animal cell vacuole? Explain why you think this is. ________________

Structure: Vacuole

Draw and label the plant cell vacuole

Function


Step 19: ____ Using the pen click on Slide 10

Slide 10:

Step 20: ____ Using the pen, remove the top layer of any of the mitochondria.

Step 21: ____ Using the pen, rotate the mitochondria to see what is inside

✓ How many mitochondria do you see? ____________
Step 22: ____ Complete the boxes below.

<table>
<thead>
<tr>
<th>Structure: Mitochondria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw the inside of the mitochondria</td>
</tr>
</tbody>
</table>

Step 23: ____ Using the pen click on Slide 11

Slide 11:

Step 24: ____ Using the pen, remove the top layer of any of the chloroplasts to see what is inside.

✓ How many chloroplasts are there? _______
✓ Why do you think that a plant cell needs so many chloroplasts? ______________________

___________________________________________________________________________

Structure: Chloroplast

Draw the inside of the chloroplasts

Function

---

Step 25: ____ Get your work checked! 😊

Part 3: Summary Questions

Using your new knowledge of cells, organelles and their questions, answer the questions that follow.

1. Complete the Venn Diagram Below

   a) Shape
   b) Organelles (specific to that cell)
   c) Life Process specifically carried out by that cell
   d) Organelles common to both cells
   e) Life Processes common to both cells
2. For part a, b and c, label the names of each cell type below as well as their organelles. Use your knowledge of what you learned from the 3D simulation to associate the structures with the NYS Regents diagrams below.

![Cell Diagrams]

a) ______________________________

b) ______________________________

c) A = ________________
   B = ________________
   C = ________________
   D = ________________
   E = ________________
   F = ________________
   G = ________________
   H = ________________

3. Below is an example of riddle about a cell organelle.
   1) Identify the organelle.
   2) Come up with your own riddle in blank box.

   1. I’m a real “powerhouse”
      That’s plain to see
      I break down food
      And release energy

      What am I? ________________

   2. Your riddle
NYS Living Environment Standards

2.1f In all organisms, the coded instructions for specifying the characteristics of the organism are carried in DNA, a large molecule formed from subunits arranged in a sequence with bases of four kinds (represented by A, G, C, and T). The chemical and structural properties of DNA are the basis for how the genetic information that underlies heredity is both encoded in genes (as a string of molecular “bases”) and replicated by means of a template.

4.1.4.4b In one type of cell division, chromosomes are duplicated and then separated into two identical and complete sets to be passed to each of the two resulting cells. In this type of cell division, the hereditary information is identical in all the cells that come from it.

NGSS Standards

HS-LS1-4. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

Rationale & Introduction

The lab *Mitotic Cell Division* allows students to learn about the phases of the cell cycle and the stages of mitosis. Students will be able to understand the importance of interphase in the creation of identical body cells in a multicellular organism. Students will also be able to recognize the stages of mitosis and understand what happens to the cell during each phase to prepare for cytokinesis. Since students cannot visualize a cell dividing, they will be able to play animations of each phase of mitosis and understand how the cellular events are crucial in helping a multicellular organism grow, develop and replace cells.

Benefits of Virtual Reality/Haptics

This lab can be used to pre-teach, teach or re-teach concepts about mitosis. The benefits of the virtual component is that it is more manipulative and experiential compared to watching videos of mitosis, which are often complex, or viewing microscope slides of mitotic phases. This lab allows students to play animations of the cell cycle and the stages of mitosis by zooming in and receiving vibration feedback when a new event happens during divisions. Students can replay and pause animations during this activity which allows them to take time to manipulate and observe the importance of each stage in the cell cycle. A major understanding that this lab will provide is the concept of passing on identical genetic information to new cells. This information will be valuable for students when they learn about mutations and the growth of a zygote into a multicellular organism. Since students will have to revisit this concept multiple times throughout the year, they will be able to link what they are learning to their experience with the animations and visuals in this lab.

Recommendations for Classroom Use

Prior to this lab, students should have prior knowledge about DNA, the importance of DNA, where DNA is found and the understanding that multicellular organisms, such as humans, are composed of many cells that carry out the life functions of the organism. This lab can be used to pre-teach the concept of mitosis accompanied by a teacher led discussion about how the students think multicellular organisms grow. Since this lab is scaffolded and offers step by step directions, students should be able to work through this lab independently or in pair to learn about the phases of the cell cycle and mitosis. Allowing the students to work through the lab at their own pace can allow them to replay and recall animations of the stages and re-vist any portion of the virtual lab to help them answer questions. With an 8th grade population, this lab would be most successful with checkpoint questions throughout the lab so the teacher can formatively assess and monitor student progress after they have completed a graphic organizer regarding the cellular process. Students should also work in pairs so neither student becomes too dizzy from overstimulation or from the 3D sensor glasses.
zSpace Lab #2: Mitotic Cell Division

Pre-Activity Questions
*Answer the questions below based on your knowledge of cells and organelles*

1. Where is a cell’s genetic material found? _________________________________________________
2. What is the name of this genetic material? ______________________________________________
3. What is a somatic cell? __________________________________________________________________
4. Hypothesize how multicellular organisms (animals, plants etc.) grow in size: ________________
   ______________________________________________________________________________________

How to Open the Program:
1. Click on “zSpace studio” on the desktop

2. Search for “Mitosis” in the search bar and click on the file
Part 1: Identifying the Phases of Mitosis
You will be guided through cellular animations and visual clips of mitotic events. Answer the questions and complete the drawings below using the given prompts.

1. Read the dialog prompt on the top left corner of the screen and answer the questions below:

   a) What is mitosis? ____________________________

   b) What kind of cells does mitosis create in a multicellular organism? ____________________________

   c) What is a diploid cell? ____________________________

   d) Why do you think it’s important that each cell that is created in mitosis has a full set of chromosomes identical to the cell that is divided from? ____________________________

2. Click the play button under the “Parent Cell.”

   Stop and replay the animation as many times as needed to complete the observations below.
1. What do you notice happening to the strands of red and blue chromosomes?

2. What shape do the chromosomes take on after a few seconds?

3. How many of these structures do you see when the parent cell is still a single cell?

4. What happens to the cell membrane of the cell?

5. How many cells result from this process?

6. How many chromosomes are in each of the cells that were created?
3. Click the arrow on the dialog prompt and **proceed to the slide 2/9**.

4. Read the dialog prompt on the top left corner of the screen and answer the questions below.
   You can also play the animation to help you.

   **a)** What does the cell have to do before it undergoes mitotic division? ____________________________
   
   What is this first phase called? _______________________________

   **b)** Looking at the cells, why do you think the chromosomes are different colors in the cell? _______
   _______________________________

5. **Complete the “Phase 1” row** on the *Mitotic Phases chart* on the next page. Click the arrow on the dialog prompt and **proceed to slide 3/9**.

6. Click the play button on the bottom right area of the screen and watch the animation.
   Play and stop the animation as many times as necessary and read the dialog prompt if needed to help you **complete the “Stage 1” row** of the *Mitotic Phases chart* on the next page.
7. When you have completed the “Stage 1” row of the Mitotic stages chart, Click the arrow on the dialog prompt and proceed to slide 4/9.

8. Click the play button on the bottom right area of the screen and watch the animation. Play and stop the animation as many times as necessary and read the dialog prompt if needed to help you complete the “Stage 2” row of the Mitotic Phases chart on the next page.

9. When you have completed the “Stage 2” row of the Mitotic stages chart, Click the arrow on the dialog prompt and proceed to slide 5/9.

10. Click the play button on the bottom right area of the screen and watch the animation. Play and stop the animation as many times as necessary and read the dialog prompt if needed to help you complete the “Stage 3” row of the Mitotic Phases chart on the next page.
11. When you have completed the “Stage 3” row of the Mitotic stages chart, Click the arrow on the dialog prompt and **proceed to slide 6/9**.

12. Click the play button on the bottom right area of the screen and watch the animation. Play and stop the animation as many times as necessary and read the dialog prompt if needed to help you **complete the “Stage 4” row** of the **Mitotic Phases chart** on the next page.

13. When you have completed the “Stage 4” row of the Mitotic stages chart, Click the arrow on the dialog prompt and **proceed to slide 7/9**.

14. Click the play button on the bottom right area of the screen and watch the animation. Play and stop the animation as many times as necessary and read the dialog prompt if needed to help you **complete the “Phase 3” row** of the **Mitotic Phases chart** on the next page.
## Mitotic Phases Chart

<table>
<thead>
<tr>
<th>Name of phase/stage</th>
<th>Drawing of Phase/Stage</th>
<th>What happens to the DNA/Chromosomes?</th>
<th>What happens to the nuclear envelope?</th>
<th>What happens to the mitotic spindles?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 1:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 2:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 3:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 4:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 1:</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Stage 2:</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Stage 3:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 4:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**STOP! GET YOUR CHART AND QUESTIONS CHECKED!**
Part 2: Summary Questions

Using your Mitotic Phases chart and information from this activity, answer the questions below to assess what you have learned about mitosis.

a. Label the structures below with the following terms:

<table>
<thead>
<tr>
<th>Chromatin</th>
<th>Nuclear Envelope</th>
<th>Chromosome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spindle Fibers</td>
<td>Cell Membrane</td>
<td>Cleavage Furrow</td>
</tr>
</tbody>
</table>

b. Each cell undergoes a cycle of about 24 hours before it divides to create new cells. What are the three major phases of the cell cycle you learned from this lab?

Phase 1: ______________________
Phase 2: ______________________
Phase 3: ______________________

a. Which of these three phases do you think takes the longest time? ______________________

b. Explain your reasoning: ______________________
   ______________________
   ______________________
   ______________________

b. Without this phase, explain why organisms could not grow, develop or replace new cells of a wound? ______________________
   ______________________
   ______________________
   ______________________
c. Below represents a human body cell with 46 chromosomes. Write in the circles how many chromosomes the resulting cells should have after cytokinesis.

a. Will the daughter cells be identical to the original parent cell? ______
b. Explain why or why not. ____________________________________________________________________
c. Using your knowledge from the genetics unit, explain how each of the cells created can have different functions in the organism. __________

__________________________________________________________________________

d. Below represents a human body cell with 46 chromosomes. Write in the circles how many chromosomes the resulting cells should have after cytokinesis if the cell did not undergo interphase.

b. Will the daughter cells be identical to the original parent cell? ______
c. Explain why or why not. ____________________________________________________________________
d. Explain why chromosome duplication is this important by relating your answer to how cells function. ____________________________________________________________________

__________________________________________________________________________

e. Fill in the blanks below using your new knowledge of mitosis and the information from this lab to summarize what you have learned.

The cell cycle contains _______ phases, _____________, _____________ and _____________. _____________ is the longest phase of the cell cycle because this is when the cell _________________ its ___________. This ensures that each cell that is created contains a _______ set of chromosomes that can carry out all cellular functions. ____________ is the second longest phase, which is when the cell undergoes a series of four _________________. At the end of these divisions, the cell pinches in and undergoes the third phase which is called _________________. At the end of this phase, _______ cells that have _____________ DNA are created. These cells will become ___________ cells, also known as body cells. Each of these cells will then undergo the ________________ and repeat the three phases again.
# zSpace Lab #3: Meiotic Cell Division

<table>
<thead>
<tr>
<th>zSpace Application</th>
<th>zSpace Studio: Meiosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Title</td>
<td>Meiotic Cell Division</td>
</tr>
<tr>
<td>Course</td>
<td>Living Environment Students (8th Grade/9th Grade students)</td>
</tr>
<tr>
<td>Unit/Topic</td>
<td>Cell Division</td>
</tr>
<tr>
<td>Time</td>
<td>60 Minutes</td>
</tr>
</tbody>
</table>

## NYS/NGSS Standards

<table>
<thead>
<tr>
<th>NYS Living Environment Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1c Mutation and the sorting and recombining of genes during meiosis and fertilization result in a great variety of possible gene combinations.</td>
</tr>
<tr>
<td>4.1c The processes of meiosis and fertilization are key to sexual reproduction in a wide variety of organisms. The process of meiosis results in the production of eggs and sperm which each contain half of the genetic information. During fertilization, gametes unite to form a zygote, which contains the complete genetic information for the offspring.</td>
</tr>
<tr>
<td>3.1h The variation of organisms within a species increases the likelihood that at least some members of the species will survive under changed environmental conditions.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NGSS Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.</td>
</tr>
</tbody>
</table>

## Rationale & Introduction

The lab *Meiotic Cell Division* allows students to learn how about the stages of meiosis and the role it plays in creating cells with genetic variation. Students will be able to recognize differences in the process of meiosis compared to mitosis and understand the importance of events in meiosis, such as crossing over and why it occurs. Since students cannot visualize a cell undergoing meiosis, they will be able to play animations of each phase of meiosis and apply this knowledge to the process of sexual reproduction and the creation of genetically diverse organisms when it is learned in the next unit.

## Benefits of Virtual Reality/Haptics

This lab can be used to pre-teach, teach or re-teach concepts about meiosis. The benefits of the virtual component is that it is more manipulative and experiential compared to watching videos of meiosis, which are often complex, or viewing microscope slides of meiotic phases. This lab allows students to play animations of the stages of meiosis by zooming in and receiving vibration feedback when a new event happens during divisions. Students can replay and pause animations during this activity, which allows them to take time to manipulate and observe the importance of each stage in meiosis. A major understanding that this lab will provide is the concept of creating four daughter cells that will become gametes with variation in their genetic information. At the end of the lab, students will be able to compare the visuals and animations of meiosis to the visuals and animations from the mitosis lab. This will allow students to understand the difference between the creation of body cells and the creation of sex cells. This information will be valuable for students when they learn about how the cells created by males and females in meiosis combine to create a new organism that will then grow larger through the process of mitosis. Since students will have to revisit this concept multiple times throughout the year, they will be able to link what they are learning to their experience with the animations and visuals in this lab.

## Recommendations for Classroom Use

Prior to this lab, students should have prior knowledge about DNA, the importance of DNA, where DNA is found the understanding that multicellular organisms, such as humans, are composed of many cells that carry out the life functions of the organism and the processes of mitosis. This lab can be used to pre-teach the concept of meiosis accompanied by a teacher led discussion and review mitosis and an introduction to the process of fertilization. Since this lab is scaffolded and offers step by step directions, students should be able to work through this lab independently or in pairs to learn about the stages of meiosis. Allowing the students to work through the lab at their own pace can allow them to replay and recall animations of the stages and re-visit any portion of the virtual lab to help them answer questions. With an 8th grade population, this lab would be most successful with checkpoint questions throughout the lab so the teacher can formatively assess and monitor student progress after they have completed a graphic organizer regarding the cellular process. Students should also work in pairs so neither student becomes too dizzy from overstimulation or from the 3D sensor glasses.
Pre-Activity Questions
Answer the questions below based on your knowledge of cells and organelles

1. What are the two categories of cell types found in a multicellular organism? ______________________
   ___________________________________________________________________________________

2. What types of cells are created by mitosis? ________________________________________________

3. What types of cells do you think meiosis creates? ____________________________________________

How to Open the Program:
1. Click on “zSpace studio” on the desktop

2. Search for “Meiosis” in the search bar and click on the file
Part 1: Identifying the Phases of Meiosis
You will be guided through cellular animations and visual clips of meiotic events. Answer the questions and complete the drawings below using the given prompts.

3. Read the dialog prompt on the top left corner of the screen and answer the questions below:

   a) What does meiosis create? ____________________________

   b) What is a haploid cell? ____________________________

   c) Hypothesize why you think it’s important that each cell that is created in meiosis has a half set of chromosomes compared to the cell that is divided from? ____________________________

4. Click the play button under the “Parent Cell.”

Stop and replay the animation as many times as needed to complete the observation questions below.
a) Write three observations you notice about the process of meiosis that differ from the process of mitosis
a. ____________________________________________________________
b. ____________________________________________________________
c. ____________________________________________________________

b) How many cells are created? __________
c) How many cell divisions occur? __________

5. Click the arrow on the dialog prompt and proceed to the slide 2/13.

6. Read the dialog prompt on the top left corner of the screen and answer the questions below.
You can also play the animation to help you

a) What does the cell have to do before it undergoes meiotic division? __________________________
What is this first phase called? ____________________________________________________________
b) Does this phase also happen in mitosis? ______________________________________________________

7. Complete the “Interphase” drawing and identifying feature on the Meiotic Phases chart on the next page. Click the arrow on the dialog prompt and proceed to slide 3/13

a) How many “parts” of meiosis are there? ________
b) What are the two parts called? ________________________________________________________________
8. Click the play button on the bottom right area of the screen and watch the animation. 
Play and stop the animation as many times as necessary and read the dialog prompt if needed to help you complete the “Prophase 1” drawing of the Meiotic Phases chart on the next page.

9. When you have completed the “Prophase 1” row of the Meiotic stages chart, Click the arrow on the dialog prompt and proceed to slide 4/13.

| a) What are homologous chromosomes? ____________________________ |
|___________________________________________________________________|
| b) Why do you think they are considered a “pair?” Where do each of the chromosomes come from? ____________________________ |
|___________________________________________________________________|
10. Click the play button on the bottom right area of the screen and watch the animation. 

Play and stop the animation as many times as necessary and read the dialog prompt if needed. When you are comfortable with the visual, complete the “Prophase 1” identifying feature of the Meiotic Phases chart on the next page.

a) What is this process called? __________________________________________________________

b) What stage of meiosis does this happen?_________________________________________________

c) Describe in words what is happening to the homologous pair during this process: ____________
_________________________________________________________________________________

_________________________________________________________________________________

d) Do you think this process causes the cells created in meiosis to be genetically identical or genetically different from each other? ___________________________ Explain why: ____________________________
_________________________________________________________________________________
_________________________________________________________________________________

11. When you have completed the “Prophase I” row of the Meiotic stages chart, Click the arrow on the dialog prompt and proceed to slide 5/13.
12. Click the play button on the bottom right area of the screen and watch the animation. Play and stop the animation as many times as necessary and read the dialog prompt if needed to help you complete the “Metaphase I” drawing and identifying feature of the Meiotic Phases chart on the next page.

![Image of animation](image1.png)

13. When you have completed the “Metaphase I” row of the Meiotic stages chart, Click the arrow on the dialog prompt and proceed to slide 6/13.

14. Click the play button on the bottom right area of the screen and watch the animation. Play and stop the animation as many times as necessary and read the dialog prompt if needed to help you complete the “Anaphase I” drawing and identifying feature of the Meiotic Phases chart on the next page.

![Image of animation](image2.png)
15. When you have completed the “Anaphase I” row of the Meiotic stages chart, Click the arrow on the dialog prompt and proceed to slide 7/13.

16. Click the play button on the bottom right area of the screen and watch the animation. Play and stop the animation as many times as necessary and read the dialog prompt if needed to help you complete the “Telophase I” drawing and identifying feature of the Meiotic Phases chart on the next page.

17. When you have completed the “Telophase I” row of the Meiotic stages chart, Click the arrow on the dialog prompt and proceed to slide 8/13.

18. Click the play button on the bottom right area of the screen and watch the animation. Play and stop the animation as many times as necessary and read the dialog prompt if needed to help you complete the “Cytokinesis” drawing and identifying feature of the Meiotic Phases chart on the next page.
At this point, you have observed and analyzed the first division of meiosis.

a) How many cells were created? _______________________________________________________

b) Are the cells identical to each other, or different? ______________________________________

c) How are the cells created after meiosis I different from the cells created in mitosis? __________

__________________________________________________________________________________

** STOP! GET YOUR CHART AND QUESTIONS CHECKED! **

19. When you have completed the “Cytokinesis I” row of the Meiotic stages chart, Click the arrow on the dialog prompt and proceed to slide 9/13.

20. Click the play button on the bottom right area of the screen and watch the animation. Play and stop the animation as many times as necessary and read the dialog prompt if needed to help you complete the “Prophase II” drawing and identifying feature of the Meiotic Phases chart on the next page.

21. When you have completed the “Prophase II” row of the Meiotic stages chart, Click the arrow on the dialog prompt and proceed to slide 10/13.

a) Look at your drawings. How is prophase I and prophase II different from each other? __________

__________________________________________________________________________________

b) How is prophase II different from prophase in mitosis? ________________________________

__________________________________________________________________________________
22. Click the arrow on the dialog prompt and **proceed to slide 11/13**.

23. Click the play button on the bottom right area of the screen and watch the animation.

Play and stop the animation as many times as necessary and read the dialog prompt if needed to help you complete the “Metaphase II, Anaphase II and Telophase II” drawing and **identifying feature** of the Meiotic Phases chart on the next page.

24. Click the arrow on the dialog prompt and **proceed to slide 12/13**.
25. Click the play button on the bottom right area of the screen and watch the animation. Play and stop the animation as many times as necessary and read the dialog prompt if needed to help you complete the “Cytokinesis” drawing and identifying feature of the Meiotic Phases chart on the next page.

At this point, you have observed and analyzed the second division of meiosis.

a) How many cells were created? ___________________________________________________

b) Are the cells identical to each other, or different? ________________________________

c) How are the cells created after meiosis II different from the cells created in meiosis I? __________
__________________________________________________________________________________

d) How are the chromosome numbers in the cells created after meiosis II different from the cells created in mitosis? __________________________________________________________________________
___________________________________________________________________________________

e) If meiosis creates sex cells, egg and sperm….

1. Will every egg a female creates be the same or different? __________________________

2. Will every sperm a male creates be the same or different? __________________________

3. Therefore, every time an egg and sperm combine to create a new organism, is there a chance they could ever create the same organism twice? __________________________

4. What specific event during meiosis happens that causes this variation? ______________

5. Explain why you think genetic diversity is important for living things: ______________
__________________________________________________________________________________
__________________________________________________________________________________

** STOP! GET YOUR CHART AND QUESTIONS CHECKED! **
<table>
<thead>
<tr>
<th>MEIOSIS I</th>
<th>MEIOSIS II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name of phase/stage</strong></td>
<td><strong>Drawing of Phase/Stage</strong></td>
</tr>
<tr>
<td>Interphase</td>
<td></td>
</tr>
<tr>
<td>Prophase I</td>
<td></td>
</tr>
<tr>
<td>Metaphase I</td>
<td></td>
</tr>
<tr>
<td>Anaphase I</td>
<td></td>
</tr>
<tr>
<td>Telophase I</td>
<td></td>
</tr>
<tr>
<td>Cytokinesis</td>
<td></td>
</tr>
<tr>
<td>zSpace Application</td>
<td>zSpace Studio: Evolution of Whales</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------------------</td>
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<tr>
<td>Lab Title</td>
<td>Evolution of the Whale</td>
</tr>
<tr>
<td>Course</td>
<td>Living Environment Students (8th Grade/9th Grade students)</td>
</tr>
<tr>
<td>Unit/Topic</td>
<td>Evolution</td>
</tr>
<tr>
<td>Time</td>
<td>40 Minutes</td>
</tr>
</tbody>
</table>

**NYS/NGSS Standards**

**NYS Living Environment Standards**

- **3.1a** The basic theory of biological evolution states that the Earth’s present-day species developed from earlier, distinctly different species.
- **3.11** Extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient to allow its survival. Fossils indicate that many organisms that lived long ago are extinct. Extinction of species is common; most of the species that have lived on Earth no longer exist.

**NGSS Standards**

- **MS-LS4-1.** Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.
- **HS-LS4-4.** Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

**Rationale & Introduction**

The lab *Evolution of the Whale* allows students to visualize the evolution of a present-day organism from its recent ancestors. Students will be able to see how traits are selected against due to their inability to aid the organism in survival. This lab will help students understand that present day organisms have come from earlier distinctly different species. Something students probably do not know, is that the present-day whale has evolved from wolf-like organisms. Students will be able to see that even though an organism may have traits that are helpful for it to live on land, a random mutation could appear that allows the organism to adapt to both land and water, causing them to increase their food options and living space, a benefit to an organism’s survival.

**Benefits of Virtual Reality/Haptics**

This lab can be used to demonstrate evolution to the students during their evolution unit or prior to learning about the theory to stimulate inquiry about the process. The benefits of observing these organisms through virtual means allows students to manipulate and analyze organisms that do not exist anymore. Since teachers would not be able to obtain fossils or models of these organisms to use in the classroom, this allows students to look at the various features of a whale’s ancient ancestors and hypothesize why these organisms have gained and lost features throughout time. Students are able to analyze each of these organisms individually and together, which allows them to see that the inheritance of certain new traits made each species so reproductively unique, they became their own species. The idea of change over time can be complex for students to understand, therefore the utilization of this lab allows students to see that change occurs over a long period of time and the changes can be minor although powerful. A major understanding that this lab will provide is the idea that populations can be impacted by changes in their environment, and if these changes are helpful for the organism’s survival it will allow them to survive, reproduce and pass these traits onto the next generation. It will also demonstrate that random DNA mutations could cause a helpful trait to appear in an organism that may allow them to adapt to a new and even more conducive environment for their survival.

**Recommendations for Classroom Use**

Prior to this lab, students should have prior knowledge about DNA, the idea that DNA gets passed onto offspring through reproduction and a general understanding of what Evolution is. This lab is a good way to pre-teach the concept of the working definition of evolution, which is that organisms change over time. This could also be used while they learn about the theory of natural selection and would be beneficial to be completed prior to the peppered moth lab. The teacher should make sure that the students understand that the evolution of organisms and new inheritable traits in a population do not occur overnight and they follow a rather gradual path. This lab should be student led and can be completed either individually or with a classmate. This lab offers step by step instructions and can be following with minimal teacher prompting so the students can explore the change in organisms over time individually. The goal is to have the students utilize the visuals and ideas in this lab to help them understand that organisms can change over time, often evolving into new organisms when they learn it in a more in depth manner in class.
Pre-Activity Questions
Answer the questions below based on your current knowledge of biology.

1. Define Natural Selection: ____________________________________________________________

2. Give an example of an organism that has evolved: ______________________________________

How to Open the Program:
1. Click on “zSpace studio” on the desktop

2. Search for “Evolution of Whales” in the search bar and click on the file
Activity: Investigating the Evolution of the Whale

You will be guided through visual prompts that will allow you to investigate the evolution of the whale.

3. Read the dialog prompt on the top left corner of the screen and answer the questions below:

<table>
<thead>
<tr>
<th>a)</th>
<th>What is a terrestrial animal?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>b)</td>
<td>What is a land-dwelling animal?</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>c)</td>
<td>Why do you think scientists hypothesized that a whale evolved from a terrestrial or a land-dwelling organism? Base your reasoning off the organisms on the screen:</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. Use the pen to hover over each organism. When you hover over it, the screen will tell you what body parts each organism has. Based on this information, arrange the ancient relative of the whale from earliest to most recent relative.

a) Write down the names of the organisms in their evolutionary order below:

________________________________________________________________________________

b) Explain why you ordered the organisms the way you did. Be sure to explain which features you took into account to create their sequence:

________________________________________________________________________________

________________________________________________________________________________
5. Proceed to the next slide. Press play below each of the organism to study their movement.

![Image of organisms]

**a)** Hypothesize what you think caused these land-dwelling animals to shift their life to living in water?

______________________________________________________________________________________________________________________________________________________________

6. Click to move onto the next slide. Here you will see the Pakicetus. Click on the tool box icon and retrieve the ruler from the tool box. Measure the length of the organism and record it in the chart on the next page in the “Pakicetus” row.

![Image of Pakicetus]
7. Once you have measured the organism, fill out the rest of the row of the chart discussing traits that make this organism similar to a wolf, a whale, and where you think the organism lived.

8. Click to move onto the next slide. Here you will see the Ambulocetus. Click on the tool box icon and retrieve the ruler from the tool box. Measure the length of the organism and record it in the chart on the next page in the “Ambulocetus” row.
9. Once you have measured the organism, fill out the rest of the row of the chart discussing traits that make this organism similar to a wolf, a whale, and where you think the organism lived.

10. Click to move onto the next slide. Here you will see the **Kutchicetus**. Click on the tool box icon and retrieve the ruler from the tool box. Measure the length of the organism and record it in the chart on the next page in the “**Kutchicetus**” row.
11. Once you have measured the organism, fill out the rest of the row of the chart discussing traits that make this organism similar to a wolf, a whale, and where you think the organism lived.

12. Click to move onto the next slide. Here you will see the Rodhocetus. Click on the tool box icon and retrieve the ruler from the tool box. Measure the length of the organism and record it in the chart on the next page in the “Rodhocetus” row.

13. Once you have measured the organism, fill out the rest of the row of the chart discussing traits that make this organism similar to a wolf, a whale, and where you think the organism lived.

14. Once you have measured the organism, fill out the rest of the row of the chart discussing traits that make this organism similar to a wolf, a whale, and where you think the organism lived.

15. Click to move onto the next slide. Here you will see the Dorudon. Click on the tool box icon and retrieve the ruler from the tool box. Measure the length of the organism and record it in the chart on the next page in the “Dorudon” row.
16. Once you have measured the organism, fill out the rest of the row of the chart discussing traits that make this organism similar to a wolf, a whale, and where you think the organism lived.

17. The **Dorudon** is the most recent ancestor to the whale. Drag the arrow to the most prominent feature the Dorudon possesses that indicates that it evolved from a terrestrial mammal.

| a) What feature did your point to? ____________________________________________________________ |
| b) Why do you think this feature does not exist in present day whales? Use your knowledge of natural selection ____________________________________________________________ |
|                                                                                           |
|                                                                                           |
|                                                                                           |
|                                                                                           |
|                                                                                           |
# Data Table: Early Ancestors of the Whale

<table>
<thead>
<tr>
<th>Organism</th>
<th>Length (cm)</th>
<th>Traits similar to a wolf</th>
<th>Traits similar to a whale</th>
<th>Lives on land, water or both? Explain 2 reasons why</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pakicetus</td>
<td></td>
<td></td>
<td></td>
<td>Land / Water / Both</td>
</tr>
</tbody>
</table>
|            |             |                          |                           | 1) ____________
|            |             |                          |                           | ____________
|            |             |                          |                           | 2) ____________
|            |             |                          |                           | ____________
| Ambulocetus|             |                          |                           | Land / Water / Both                                   |
|            |             |                          |                           | 1) ____________
|            |             |                          |                           | ____________
|            |             |                          |                           | 2) ____________
|            |             |                          |                           | ____________
| Kutchicetus|             |                          |                           | Land / Water / Both                                   |
|            |             |                          |                           | 1) ____________
|            |             |                          |                           | ____________
|            |             |                          |                           | 2) ____________
|            |             |                          |                           | ____________
| Rodhocetus |             |                          |                           | Land / Water / Both                                   |
|            |             |                          |                           | 1) ____________
|            |             |                          |                           | ____________
|            |             |                          |                           | 2) ____________
|            |             |                          |                           | ____________
| Dorudon    |             |                          |                           | Land / Water / Both                                   |
|            |             |                          |                           | 1) ____________
|            |             |                          |                           | ____________
|            |             |                          |                           | 2) ____________
|            |             |                          |                           | ____________

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Summary:

1. Proceed to the final slide.

a) What process caused the new traits to appear in each of the different organisms? ______________

b) Why don’t these organisms exist anymore? __________________________________________________________________________

____________________________________________________________________

c) Summarize what you learned about the evolution of the whale using your knowledge of this simulation as well as the theory of natural selection. Be sure to use the following terms at least once: land dwelling organisms, aquatic organism, wolf, whale, hind limbs, webbed feet, Pakicetus, Ambulocetus, Kutchicetus, Rodhocetus, Dorodon, evolution, natural selection, selected for, selected against. __________
# zSpace Lab #5: Natural Selection of the Peppered Moth

<table>
<thead>
<tr>
<th><strong>zSpace Application</strong></th>
<th>zSpace Studio: Peppered Moth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lab Title</strong></td>
<td>Natural Selection of the Peppered Moth</td>
</tr>
<tr>
<td><strong>Course</strong></td>
<td>Living Environment Students (8th Grade/9th Grade students)</td>
</tr>
<tr>
<td><strong>Unit/Topic</strong></td>
<td>Evolution</td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td>40 Minutes</td>
</tr>
</tbody>
</table>

### NYS/NGSS Standards

#### NYS Living Environment Standards

- **3.1f** Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring.

- **3.1g** Some characteristics give individuals an advantage over others in surviving and reproducing, and the advantaged offspring, in turn, are more likely than others to survive and reproduce. The proportion of individuals that have advantageous characteristics will increase.

- **3.1h** The variation of organisms within a species increases the likelihood that at least some members of the species will survive under changed environmental conditions.

#### NGSS Standards

- **HS-LS4-2.** Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

- **HS-LS4-4.** Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

### Rationale & Introduction

The lab *Natural Selection of the Peppered Moth* allows students to learn how an organism’s environment can have an impact on the reproductive success of the populations. Students will learn about a particular scenario that inspired many people to begin to believe Darwin’s theory of Natural Selection. Students will be able to re-acquaint themselves with the time-period during the Industrial Revolution and how it impacted the environment. They will observe populations of peppered moths and how their survival rates vary depending on their environment. Students will learn that organisms that cannot adapt to their changed surroundings can either survive due to their inherited genetic variations, reproduce and pass those traits on, or they can die due to their inherited genetic variations. Students will be able to visually witness a shift in populations overtime due to environmental changes.

### Benefits of Virtual Reality/Haptics

This lab can be used to pre-teach or teach the concept of natural selection. The idea of natural selection is a complex idea that is often difficult for students to understand as it is not a “process.” The benefits of the virtual component of this lab is that students get to analyze a scenario in which a population of organisms are acted on through natural selection. Students can make detailed observations about the habitats and how they can have an effect on the survival rate of organism. This simulation allows students to become acquainted with an environment and a real-life scenario that you cannot encounter through typical class laboratory settings. A major understanding that this lab will provide is the idea that populations can be impacted by changes in their environment, and if their genetics allow them to survive in the changing environment they can survive, reproduce, and pass their traits onto their offspring. Students cannot witness a population of organisms reproduce to numerous amounts in a lab setting, so this simulation can offer them the visualization of “reproductive value.”

### Recommendations for Classroom Use

Prior to this lab, students should have prior knowledge about DNA, the idea that DNA gets passed onto offspring through reproduction and a general understanding of what Evolution is. This lab is a good way to pre-teach the concept of natural selection accompanied by a teacher led discussion about the term adaptation, what it means and examples of it. The teacher should also discuss with the students that Charles Darwin’s idea of evolution through natural selection was often argued since many people could not witness his evidence “within their lifetime.” This will help introduce the importance of this peppered moth example, a true scenario of natural selection occurring in front of the eyes of human beings that debated his argument. This lab should be student led and can be
completed either individually or with a classmate. This lab offers step by step instructions and can be following with minimal teacher prompting so the students can explore the scenario of natural selection on their own. The goal is to have the students utilize the visuals and ideas in this lab to help them understand the theory of natural selection when they learn it in a more in depth manner in class.

**zSpace Lab #5: Natural Selection of the Peppered Moth**

**Pre-Activity Questions**

*Answer the questions below based on your current knowledge of biology.*

1. Define adaptation: ____________________________________________________________
2. Give an example of an organism that has a characteristic that helps them survive: ______________________
   ____________________________________________________________
3. How could you define “Natural Selection” in your own words: ______________________
   ____________________________________________________________

**How to Open the Program:**

1. Click on “zSpace studio” on the desktop
2. Search for “Peppered Moth” in the search bar and click on the file
Activity: Investigating Natural Selection of the Peppered Moth
You will be guided through visual prompts that will allow you to investigate the evolution through natural selection of the Peppered Moth.

1. Read the dialog prompt on the top left corner of the screen and answer the questions below:

   a) Describe three similarities between these two moths: ________________________________
      ________________________________
      ________________________________

   b) Describe three differences between these two moths: ________________________________
      ________________________________
      ________________________________

   c) What do you think causes the color variation between these two moths? ________________________________
      ________________________________

2. Click the button to proceed to the next slide. Click on the button so you can retrieve the ruler tool.
3. Click on the ruler icon and drag it over to each moth to take their measurements. Write their measurements below.

Peppered Moth: _________ mm
Black Moth: ____________ mm

4. Click the button to proceed to slide 3.
a) Hover over the tree and the log. What is the exact name of these two “habitats?

_________________ and ____________________

b) Describe both habitats by giving two detailed observations about each habitat: ____________________

c) Place both moths on the log. Which one blends in more? ____________________
d) Place both moths on the log. Which one blends in more? ____________________

5. Click the button to proceed to slide 4.
a) Place both moths on the tree. Which one blends in more?

b) Place both moths on the tree. Which one blends in more?

c) State a conclusion regarding moth color and their survival in each habitat:


d) Why is camouflage so important for organisms in their habitats? Give at least two reasons why:

6. Click the button to proceed to slide 6. Read the dialog prompt to answer the questions that follow.

a) Where was the study of these peppered moths done?

b) Was this before, during or after the industrial revolution?

c) Which moths were more prevalent in this area? Why do you think they were more prevalent?


d) Which moths were less prevalent in this area? Why do you think they were less prevalent?
e) What happened to the moths that could not camouflage in the environment?

f) **Fill in the blank**: In this population, the ________________ moths survived. Since they survived, the ________________ moths were able to reproduce and create more ________________ moths. This ________________ the amount of ________________ moths in the population and ________________ the amount of ________________ moths in the population because they could not survive, reproduce and create more ________________ moths.

7. Click the **button** to proceed to slide 7. Read the dialog prompt to answer the questions that follow.

a) What was the industrial revolution?

b) What did the industrial revolution do to the environment?

c) What do you notice that is different about the moth’s environment?

d) Which moths do you think can best adapt to this environment? Explain why:

e) Explain how the population of moths will differ during the industrial revolution compared to before the industrial revolution:
8. Click the button to proceed to slide 8. Read the dialog prompt to answer the questions that follow.

**a)** After the industrial revolution, the population shifted from the light-colored moths being the most prevalent to the black moths being the most prevalent. Explain in your own words why this happened. In your answer be sure to include the following terms once or more than once: *light moth, dark moth, survive, reproduce, pass on, genes, offspring, predator, camouflage, most abundant, least abundant*

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

**b)** Hypothesize what you think will happen to both moth populations if the air quality improves and explain why ____________________________

_____________________________________________________________________
_____________________________________________________________________

**c)** Are inherited genetic variations ALWAYS either *helpful or harmful*? Explain your reasoning: __________

_____________________________________________________________________
_____________________________________________________________________

<table>
<thead>
<tr>
<th>zSpace Application</th>
<th>zSpace Studio: Abiotic vs. Biotic Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Title</td>
<td>Biotic and Abiotic Factors of the Environment</td>
</tr>
<tr>
<td>Course</td>
<td>Living Environment Students (8th Grade/9th Grade students)</td>
</tr>
<tr>
<td>Unit/Topic</td>
<td>Ecology</td>
</tr>
<tr>
<td>Time</td>
<td>40 Minutes</td>
</tr>
</tbody>
</table>

**NYS/NGSS Standards**

- **NYS Living Environment Standards**
  - 6.1e In any particular environment, the growth and survival of organisms depend on the physical conditions including light intensity, temperature range, mineral availability, soil/rock type, and relative acidity (pH).
  - 6.1g Relationships between organisms may be negative, neutral, or positive. Some organisms may interact with one another in several ways. They may be in a producer/consumer, predator/prey, or parasite/host relationship; or one organism may cause disease in, scavenge, or decompose another.
  - 6.3a The interrelationships and interdependencies of organisms affect the development of stable ecosystems.

- **NGSS Standards**
  - HS-LS2-8. Evaluate evidence for the role of group behavior on individual and species’ chances to survive and reproduce.

**Rationale & Introduction**

The lab *Biotic and Abiotic Factors in the Environment* allows students to introduce themselves to both the living and the nonliving physical factors in the environment. Students will be able to explore the importance of having both factors in an ecosystem to keep it self-sustaining, discuss the specific processes living things will carry out through the use of abiotic resources and discover what could happen to an ecosystem if one or more of these resources is removed. This lab will help students understand that something as simple as a change in temperature, an abiotic factor, can alter an entire ecosystem and affect all things living in the ecosystem either directly or indirectly.

**Benefits of Virtual Reality/Haptics**

This lab offers a visual depiction of the living and nonliving counterparts of an ecosystem. Although students may be familiar with all of the models used in this simulation, they may not understand why these certain things are classified as living or nonliving. Students can encounter most of these biotic and abiotic factors in their daily lives, therefore becoming familiar with the importance of these factors can enhance their understanding of the importance of the interaction among these factors. Having a base understanding of the components of an ecosystem will help students throughout the unit when they learn about the different types of relationships between organisms and what can happen when an ecosystem has limited amounts of these biotic and abiotic factors.

**Recommendations for Classroom Use**

Prior to this lab, students should understand the foundations of ecology, such as the definition of ecology and what an ecosystem is. This lab would be best used to pre-teach the ideas of environmental factors so students can have a self-guided exploration through an ecosystem and identify the important components. This lab offers step by step instructions and can be followed with minimal teacher prompting so the students can explore the relationships that exist in an ecosystem individually. The goal is to have the students utilize the visuals and ideas in this lab to help them understand that organisms rely on various other living organisms as well as non-living factors to sustain life. Without these factors, an ecosystem would not be able to maintain equilibrium.
Pre-Activity Questions

Answer the questions below based on your current knowledge of biology.

1. Define Ecosystem: ____________________________

2. Why do organisms interact with their environment? ____________________________

3. Name an organism, a life process that it carries out, and the materials that this organism requires to perform this process. ____________________________

How to Open the Program:

1. Click on “zSpace studio” on the desktop

2. Search for “Abiotic vs. Biotic” in the search bar and click on the file
Activity: Identifying Biotic and Abiotic Factors in the Environment

You will be guided through visual prompts that will allow you to investigate biotic and abiotic components of an ecosystem.

1. Read the dialog prompt on the top left corner of the screen and answer the questions below:

   a) Observe images you see on your screen. Take your pen, pull them out, look at them and make observations. When you have observed everything, create two categories of your choice in the data table below and categorize what you see on the screen into two groups.

<table>
<thead>
<tr>
<th>Category 1: __________________________</th>
<th>Category 2: __________________________</th>
</tr>
</thead>
</table>

   b) Explain why you chose these categories and your thinking process when placing the objects into these categories: ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
2. Proceed to the next slide. Many scientific terms come from the Greek language.

<table>
<thead>
<tr>
<th>a)</th>
<th>What word do you recognize in the word “biotic”?</th>
</tr>
</thead>
<tbody>
<tr>
<td>b)</td>
<td>What do you think the word biotic means?</td>
</tr>
</tbody>
</table>

a) Were you correct? ________ What does the word biotic mean? ____________________________

b) Which objects on the screen are biotic? __________________________________________________
4. Proceed to the next slide.

![Image of abiotic context]

**a)** What do you think the work “abiotic” means? ____________________________________________

5. Proceed to the next slide.

![Image of abiotic context]

**a)** Were you correct? ____________ What does the word Abiotic mean? ________________________________

**b)** Which objects on the screen are Abiotic? ____________________________________________
6. Proceed to the next slide. Observe this scene by grabbing objects and looking at them closely.

a) Complete the chart below identifying at least 5 biotic and 5 abiotic factors in this scene.

<table>
<thead>
<tr>
<th>Biotic Factors</th>
<th>Abiotic Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
7. Proceed to the next slide. Many organisms depend on their abiotic counterparts and many organisms are depending on one another either directly or indirectly.

a) If all of the rain dried up, which organism would be the first affected? ______________________________

b) Which organism would be affected next? _______________________________ Explain why: ______

__________________________

c) What does this tell you about the dependence or organism on each other and the physical abiotic factors in the environment? ________________________________

__________________________
8. Proceed to the next slide. Place the object on the screen into their appropriate categories.

a) Why did you place certain objects under the biotic category? Explain three reasons why they are “biotic”
   - 
   - 
   - 

b) Why did you place certain objects under the abiotic category? Explain three reasons why they are “abiotic”
   - 
   - 
   - 

c) Analyze your objects. What features to the biotic factors have that the abiotic factors do not have that allow them to carry out the functions of a living thing?

   - 

   - 

   - 

d) Give two examples of how a biotic factor in this scene interacts with an abiotic factor and why their interaction is important:
   - 
   - 
   - 

   - 

9. Proceed to the next slide. Here you will see an image of a tree as well as other biotic and abiotic factors. As you have learned, interactions between these two environmental factors help organisms grow, survive and reproduce.

![Image of a tree and other environmental factors]

** a) Name two biotic factors the plant depends on. Explain why a plant needs both factors **

- Plants need ________________________ because ________________________________

- Plants need ________________________ because ________________________________
10. Proceed to the next slide. Here you will see a variety of organisms depending on each other as well as their physical environment.

a) The crab is a biotic factor depending on the rock, an abiotic factor. Explain why the crab needs the rock to help it survive: ________________________________

b) The brain coral is a biotic factor in this ecosystem. Examine its shape, color and texture.
   a) What organism lives in the coral? ________________________________
   b) What is the name for the relationship this organism has with the coral? ________________________________
   c) How does the coral help this organism, and how does the organism help the coral? ________________________________
   d) What would happen to the coral if it did not have this organism living in it? ________________________________
   e) Name another mutualistic relationship in this scene ________________________________
11. Proceed to the next slide.

a) Explain why it is important for the abiotic factor, temperature, to remain stable in the coral’s environment. 

12. Proceed to the next slide. Arrange the models to create a scene that shows the abiotic and biotic factors interacting. Label each model abiotic or biotic. Show your teacher your scene.
a) Explain the interactions in your scene

b) Although abiotic factors are not considered living, explain why it is important that these factors are available to the biotic factors

c) What would happen if the abiotic and biotic factors in ecosystems became limited

**STOP! GET YOUR QUESTIONS CHECKED!**
### zSpace Application

<table>
<thead>
<tr>
<th>zSpace Studio: Interactions in the Savanna</th>
</tr>
</thead>
</table>

### Lab Title

Community Interactions

### Course

Living Environment Students (8th Grade/9th Grade students)

### Unit/Topic

Ecology

### Time

60 Minutes

### NYS/NGSS Standards

<table>
<thead>
<tr>
<th>NYS Living Environment Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1e In any particular environment, the growth and survival of organisms depend on the physical conditions including light intensity, temperature range, mineral availability, soil/rock type, and relative acidity (pH).</td>
</tr>
<tr>
<td>6.1g Relationships between organisms may be negative, neutral, or positive. Some organisms may interact with one another in several ways. They may be in a producer/consumer, predator/prey, or parasite/host relationship; or one organism may cause disease in, scavenge, or decompose another</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NGSS Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-LS2-6. Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions but changing conditions may result in a new ecosystem.</td>
</tr>
<tr>
<td>HS-LS2-8. Evaluate evidence for the role of group behavior on individual and species’ chances to survive and reproduce.</td>
</tr>
</tbody>
</table>

### Rationale & Introduction

The lab *Community Interactions* allows students to explore one of the most diverse biomes, the grasslands in the Savanna. Here the students will be able to see the variety of biotic and abiotic factors in a diverse biome and analyze the various possible relationships that can exist in an ecosystem. Students will be able to utilize their knowledge of evolution from the previous unit and link it to concepts learned in this lab. This lab will help students understand that although some relationships between living things may be negative, there are also positive relationships that exist between organisms that can affect all the living things in that environment whether it is directly or indirectly.

### Benefits of Virtual Reality/Haptics

This lab can be used to observe and analyze why certain organisms undertake various roles in the community. Students will be able to observe a population that they are not able to observe directly, such as the grasslands. The virtual features of this lab will allow students to carefully analyze the specific adaptations of organisms such as trees, lions, zebras, ants and other organisms and discover the certain features these organisms have that allow them to be successful when competing for limited resources, preying on organisms or hiding from predators. Since students cannot encounter most of these organisms daily, the haptic features enhance the exploration of these organisms features by being able to get close to and look inside these organisms. Students will also discover the potential outcome of removing certain organisms or abiotic factors from the environment and understand how that can influence the entire community. Students are unable to manipulate an entire ecosystem of species; therefore this simulation is a vehicle to allow students to tinker with possible ecological and evolutionary factors that could alter an ecosystem and understand that there is a certain natural stability found in every ecosystem.

### Recommendations for Classroom Use

Prior to this lab, students should have prior knowledge about evolution and the fundamentals of ecology, such as biotic factors and abiotic factors. Students will naturally have some background knowledge about community interactions in an ecosystem, such as predator-prey relationships and competition between organisms, therefore this lab can be used to introduce the ideas of ecological relationships prior to learning it in class. It would be beneficial to have a post-discussion after the completion of this lab that prompts students to discuss the importance of the biodiversity or the organisms in the environment. This lab should be completed prior to teaching the students about human impact on the environment so they can link their understanding of the importance of diversity in ecosystems to what they learn during the human impact unit. This lab offers step by step instructions and can be followed with minimal teacher prompting so the students can link their prior knowledge of evolution and ecology to this lab. The goal is to have the students utilize the visuals and
170 ideas in this lab to help them understand that there are various relationships that exist in ecosystems and that each organism has a vital role in maintaining the stability of the environment, no matter how minor of an organism they may seem.

**zSpace Lab #7: Community Interactions**

**Pre-Activity Questions**
*Answer the questions below based on your current knowledge of biology.*

1. Give an example of a type of ecological relationship that could exist between two organisms: __________
   ____________________________________________________________________________

2. Why do organisms have to interact with one another and their environment? ________________
   ____________________________________________________________________________

3. List what you know about the grassland Biome, Savanna: ____________________________
   ____________________________________________________________________________
   ____________________________________________________________________________

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How to Open the Program:
1. Click on “zSpace studio” on the desktop
2. Search for “Interactions in the Savana” in the search bar and click on the file

Activity: Investigating Ecological Relationships in the Savanna
You will be guided through visual prompts that will allow you to investigate ecological relationships
1. Read the dialog prompt on the top left corner of the screen and press the play button on the bottom right corner of your screen. Answer the questions below.
2. Click to proceed to the next slide. Read the dialog prompt and answer the questions below.
a) Identify the three main types of interactions that exist between organisms in the environment. Try to define each one to the best of your ability based on your prior knowledge.

1. ______________________: __________________________________________________________

2. ______________________: __________________________________________________________

3. ______________________: __________________________________________________________

b) What is the definition of the term “limited resource”:

_______________________________________________________________________________

c) Name two possible limited resources in this environment that these organisms would compete for: _____
_______________________________________________________________________________

d) What are two physical characteristics that all of these organisms have in common that you think make it successful for them to live in the same environment: ____________________________________________
_______________________________________________________________________________

3. Proceed to the next slide. Read the dialog prompt and answer the questions below.
a) Name two limited resources that these different types of plant species may compete for: __________

4. Proceed to the next slide. Read the dialog prompt and answer the questions below.
a) Define **adaptation**: 

b) Using the camera on the screen, zoom into each of the plant species on the screen. In the chart below, list at least 4 adaptations that these plants possess that allow them to reduce their competition for limited resources.

<table>
<thead>
<tr>
<th>Adaptation</th>
<th>Explain how this adaptation reduces competition of limited resources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Proceed to the next slide. Read the dialog prompt, press the play button below to observe the interactions in the environment and answer the questions below.

a) Define **competition**: 

b) Give two examples of organisms in this scene that may undergo competition for limited resources. Use evidence to support your answer as to why you think they would compete and what would they compete for.
   1. _________________ and _________________ would compete for _________________
      because ______________________________________________________________________
      ______________________________________________________________________
   2. _________________ and _________________ would compete for _________________
      because ______________________________________________________________________
      ______________________________________________________________________
6. Proceed to the next slide. Read the dialog prompt, press the play button below to observe the interactions in the environment and answer the questions below.

a) Define **predation**: 

b) Sort the animals above into a “predator” category and a “prey” category. Scroll over the organism to obtain their name if you are unsure what they are. List the animals below.

<table>
<thead>
<tr>
<th>Predators</th>
<th>Prey</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
c) Identify one prey organism above and explain what traits it may have that are disadvantageous to surviving predation:

7. Proceed to the next slide. Read the dialog prompt and answer the questions below.

a) Name two adaptations this predator has that allows them to help catch prey. Zoom in and out and manipulate the predator to observe its traits. Explain why they are advantageous:

- Trait: __________________ it is helpful because: __________________
- Trait: __________________ it is helpful because: __________________

8. Proceed to the next slide. Read the dialog prompt and answer the questions below.
a) Explain how the coloration of the zebras help them to avoid being preyed on: ____________________________

b) What do you think would happen if a genetic mutation accounted for an all-white or an all-black zebra? ____________________________

9. Proceed to the next slide. Read the dialog prompt and press play to observe the scene on your screen. Answer the questions below.

a) If a disease killed a large percentage of the wildebeest population, how would the lion population be affected? ____________________________

b) How would the zebra population be affected? ____________________________

c) Explain in your own words why predators and their prey rise and fall in related cycles: ____________________________

10. Proceed to the next slide. Read the dialog prompt and press play to observe the scene on your screen. Answer the questions below.


a) If the waterhole dries up, name one species that would be affected and why? ____________________________

b) Name another species that would be affected by the loss of the species in your answer to letter a. Explain why: ____________________________

11. Proceed to the next slide. Read the dialog prompt and press play to observe the scene on your screen. Answer the questions below.

a) Define **symbiosis:** ____________________________

b) Define **mutualism:** ____________________________

c) Explain how the relationship between the ants and the acacia tree an example of a mutualistic symbiotic relationship is. Be sure to identify how each organism plays a role in this relationship: ____________________________

______________________________
12. Proceed to the next slide. Read the dialog prompt and press play to observe the scene on your screen. Answer the questions below.

a) Explain how an elephant could cause an end to the mutualistic relationship between the ants and the tree:

__________________________________________________________________________________________

__________________________________________________________________________________________

Summary:
Proceed to the final slide and example the biotic and abiotic features in the environment. Answer the questions below to summarize what you’ve learned in this simulation.
a) List a **biotic factor** in this environment: ________________________________

b) List an **abiotic factor** in this environment: ________________________________

c) Explain how this biotic factor relies on this abiotic factor for survival: ________________________________

d) Explain what would happen if this abiotic factor became limited: ________________________________

e) Name another biotic factor that relies on this abiotic factor: ________________________________

f) What type of **relationship** would occur between your two biotic factors if this abiotic factor became limited? ________________________________

g) Give an example of a **predator** in this environment: ________________________________

h) Name a **prey** organism that your predator would prey on: ________________________________

i) Name an adaptation your predator has that gives it an advantage when preying on organisms: ________________________________

j) Name an adaptation your prey may have that could allow it to avoid predation: ________________________________

k) Give an example of a **mutualistic relationship** that may exist among two organisms in this environment. Explain how each benefits the other: ________________________________

l) Break up the term **BIODIVERSITY.** What do you think this word means in terms of ecology? ________________________________

m) Why do you think biodiversity is important in an ecosystem? ________________________________

n) What did this lab teach you about the relationship between the variety of organisms that exist in an ecosystem and the stability of the ecosystem? ________________________________

** STOP! GET YOUR WORK CHECKED! **
<table>
<thead>
<tr>
<th>zSpace Application</th>
<th>Newton’s Park: Forces and Motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Title</td>
<td>How Does Force Affect an Object’s Motion?</td>
</tr>
<tr>
<td>Course</td>
<td>Physical Science (7th Grade Students)</td>
</tr>
<tr>
<td>Unit/Topic</td>
<td>Forces</td>
</tr>
<tr>
<td>Time</td>
<td>40 Minutes</td>
</tr>
</tbody>
</table>

**NYS/NGSS Standards**

- **NYS Intermediate Science Standards**
  - 5.1b The motion of an object can be described by its position, direction of motion, and speed.
  - 5.1c An object’s motion is the result of the combined effect of all forces acting on the object. A moving object that is not subjected to a force will continue to move at a constant speed in a straight line. An object at rest will remain at rest.

- **NGSS Standards**
  - **MS-PS2-2.** Plan an investigation to provide evidence that the change in an object’s motion depends on the sum of the forces on the object and the mass of the object.

**Rationale & Introduction**

The lab *How Does Force Affect an Object’s Motion?* allows students to understand that forces cause object to move. Students will be able to observe force areas with either one force or two opposing forces acting on an object. They will observe how far the ball moves in each experimental force field and create a conclusion about the magnitude of a force as well as an object’s motion. Observations during this simulation will encourage students to observe the sum of forces acting on objects in their everyday lives and plan an investigation to see how opposing forces can also stop an object’s motion.

**Benefits of Virtual Reality/Haptics**

This lab can be used to pre-teach, teach or re-teach concepts about the affect forces have on an object’s motion. Although students can apply forces to object in real life, the benefit of virtually observing various magnitudes of forces on an object allows students to study the affect in a controlled environment. If students were to mimic this lab in a classroom, they would have to measure the force applied to the object each time to make sure it was an experimental constant in each experiment. This allows students to focus on their observations and replay or pause the animations multiple times to observe the effects. A major understanding that this lab will provide is the concept that there are multiple forces, whether they are balanced or unbalanced, that act on various objects every day and the sum of these forces are what interacts to move an object a certain distance or remain stationary. The haptic component of this lab will provide students with the ability to receive feedback when each ball is launched as well as when each ball reaches the end of each experiment.

**Recommendations for Classroom Use**

Since this lab can serve as an introduction to forces or be used while teaching about forces, students can have prior knowledge about what a force is and the concept that forces cause objects to move, however this lab can also be utilize to discover that concept. The use of this lab will help students visualize what a force is and how forces with different magnitudes can cause objects to change their motion. This lab is scaffolded and offers step by step directions for the students to follow either independently or with a classmate. Students should be allowed to work at their own pace and replay and create their own experiments multiple times to understand the main concepts of this lab.
zSpace Lab #8: How Does Force Affect an Object’s Motion?

Pre-Activity Questions
*Answer the questions below based on your knowledge and predictions of forces and the motion of objects*

1. Define Force: _________________________________________________________________

2. Explain a scenario where a force is acting on an object that makes it move: ______________
   _________________________________________________________________

3. Explain a scenario where forces act on an object, but it does not move: ______________
   _________________________________________________________________

4. Do you think if an object *moves* it is an unbalanced force or a balanced force? ______________

5. Do you think if an object *does not move* it is an unbalanced force or a balanced force? ______________
How to Open the Program:
1. Click on “Newton’s Park” on the desktop

2. Search for “Forces in Motion” in the search bar and click on the file

Activity: Observing a Force Area and Making Predictions
You will be observing four experiments that involve various forces acting on an object. Follow the prompts below and answer the questions that follow.

1. Observing the experiments below, answer the questions that follow.:
e) The screen you are on represents four different experiments. List two similarities and two differences between the experiments below:

**Similarities:**  
-  
-  

**Differences:**  
-  
-  

f) Using the pen, hover over the forces on each experiment. There are two forces acting on each experiment. Examine them and answer the questions below by circling whether is it a balanced or unbalanced force as well as identifying the magnitude of each force.

a) **Experiment 1:** (balanced/unbalanced) forces of _____ N and _____ N  
b) **Experiment 2:** (balanced/unbalanced) forces of _____ N and _____ N  
c) **Experiment 3:** (balanced/unbalanced) forces of _____ N and _____ N  
d) **Experiment 4:** (balanced/unbalanced) forces of _____ N and _____ N
g) The same ball will move through the series of forces in each experiment. Using the guide on the “floor” of this experiment, each square is equal to 1m. Predict how far each ball will travel in meters based on each experiment’s force area.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>__________</td>
</tr>
<tr>
<td>2</td>
<td>__________</td>
</tr>
<tr>
<td>3</td>
<td>__________</td>
</tr>
<tr>
<td>4</td>
<td>__________</td>
</tr>
</tbody>
</table>
2. Launch the experiments by pressing the button. This will release the balls through their individual force areas. You can play this back as many times as needed and pause it at any point of the animation.

You can also press the button, which will give you a more detailed view as well as the options to fast forward, rewind and slow down the animation.
a) Annotate the diagram below to represent the results of the experiment. **Be sure to include the following for each experiment:** The direction of the forces using arrows, the magnitude of each force, the ending point of the ball when the launch ends, and the distance each ball travelled in meters.

![Diagram](image)

b) Compare launch 1 and 2 when the ball moves out of the area of force. Which experiment caused the ball to move faster and farther? Explain why:

**Experiment # ____** because ________________________________

__________________________

c) Describe the motion of the ball in experiment 3. Why do you think the ball moved the way it did? ____

__________________________

d) Describe the motion of the ball in experiment 4. Which other experiment was similar to the motion of the ball in experiment 4? ________________________________

__________________________

e) State a conclusion about the relationship between force and the distance an object travels: __________

__________________________

f) Create an experiment by adding two forces to a force area so the ball does not move. Draw your experiment below indicating the direction of the forces, the magnitude of the forces, and the distance the ball will travel.

![Diagram](image)
### zSpace Lab #9: How Does Friction Affect an Object’s Motion?

<table>
<thead>
<tr>
<th>zSpace Application</th>
<th>Newton’s Park: Discovering Friction: Part 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Title</td>
<td>How Does Friction Affect an Object’s Motion?</td>
</tr>
<tr>
<td>Course</td>
<td>Physical Science (7th Grade Students)</td>
</tr>
<tr>
<td>Unit/Topic</td>
<td>Forces</td>
</tr>
<tr>
<td>Time</td>
<td>40 Minutes</td>
</tr>
</tbody>
</table>

#### NYS/NGSS Standards

<table>
<thead>
<tr>
<th>NYS Intermediate Science Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2d Friction is a force that opposes motion.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NGSS Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS-PS2-2. Plan an investigation to provide evidence that the change in an object’s motion depends on the sum of the forces on the object and the mass of the object.</td>
</tr>
</tbody>
</table>

#### Rationale & Introduction

The lab *How Does Friction Affect an Object’s Motion?* allows students to understand that friction is a force that always exists between two objects. Whether it is your feet against the floor, a ball falling through air, or a ball rolling across the floor, friction is always present and can affect an object’s motion. Students will be able to observe friction in a controlled environment by launching objects made of different materials across various floor materials. Students will make observations about how far each block travels on each material and make connections between the distance each ball traveled, and the amount of friction created between the objects. Although friction is not something that can be seen, this simulation will encourage students to think about the friction they encounter in their daily lives. At the end of this simulation, students will be able to conclude that if there is more friction created between objects, the slower an object will move. However, this will lead them to think about situations in which increased friction or decreased friction can be a benefit for objects in motion.

#### Benefits of Virtual Reality/Haptics

This lab can be used to pre-teach, teach or re-teach concepts regarding friction and how it has an affect on an object’s motion. The benefit of virtually observing the friction created between various objects allows students to study the affect in a controlled environment. If students were to mimic this lab in a classroom, they would have to gather various objects of the same size created from different materials and be sure to launch them with the same exact force along various surfaces. The surfaces used in this lab are very different from each other and may not be able to be replicated in a classroom. The virtual component allows students to focus on their observations and replay or pause the animations multiple times to observe the effects of friction on an object’s motion. A major understanding that this lab will provide is the concept that friction exists between two surfaces that come in contact with one another and that the force of friction varies depending on the materials the object are made of. Students will be able to feel the differences in friction by receiving haptic feedback and they will be able to utilize the features of zSpace to zoom in and analyze the unique characteristics of each object and surface to see how their characteristics affect the force of friction.

#### Recommendations for Classroom Use

Since this lab can serve as an introduction to friction or be used while teaching friction, students can have prior knowledge about what friction is and how it can affect objects in motion, however this lab can also be utilized to discover that concept. Since friction cannot be “seen,” this will help students visualize what friction is and how the materials that come in contact with each other can affect how slow or fast an object moves. This lab is scaffolded and offers step by step directions for the students to follow either independently or with a classmate. Students should be allowed to work at their own pace and replay and create their own experiments multiple times to understand the main concepts of this lab.
**Pre-Activity Questions**
*Answer the questions below based on your knowledge and predictions of forces and the motion of objects*

1. **Define Friction:** _______________________________________________________________________

2. **Explain a scenario where you have encountered friction:** ______________________________________

3. **Do you think it is easier to move a metal box along a platform of ice or a rug? Explain why:** ______

   ______________________________________________________________________________________
How to Open the Program:
1. Click on “Newton’s Park” on the desktop
2. Search for “Discovering Friction: Part 2” in the search bar and click on the file

Part 1: Determining How an Object’s Motion is affected by Friction
You will be conducting an investigation to determine how various surfaces can affect the motion of different objects. Read the directions below and answer the questions that follow.

1. Using your pen, click on the icon and select three of the objects that appear.
2. Place each of your three chosen objects in front of a launcher below.
a) Explain why you chose these three objects: _____________________________________________

b) If you hover over each object, it will tell you the material they are made of. Record the name of the three objects you chose in the **first column** of the **data table** on the next page where it says “**Block Material**”. You will be referring to this data table for the next series of questions.

3. The first platform you will be using is **Wood**. Select this platform by clicking on the icon. Hover over each choice until you find wood.
4. Using the pen, drag the wood icon onto the platform.

a) Describe the wood material using three words: ________________________________

b) Which of your three blocks do you think will travel the farthest? ________________
   Explain why: ________________________________________________________________
5. Press the button to launch your three objects across the wood platform. Pause the animation as many times as needed.

6. Measure how far each block traveled by using the floor grid as a guide. Each “box” is equal to 1 m. Record the distance each block traveled in the “Wood” column of the data table on the next page.

7. Click the button to reset the blocks back to their starting positions.

8. The second platform you will be using is Metal. Select this platform by clicking on the icon. Hover over each choice until you find metal.

9. Using the pen, drag the metal icon onto the platform.
a) Describe the **metal** material using three words: ________________________________

b) Which of your three blocks do you think will travel the farthest? ________________________________
   Explain why: ________________________________

10. Press the button to launch your three objects across the metal platform. Pause the animation as many times as needed.

11. Measure how far each block traveled by using the floor grid as a guide. Each “box” is equal to 1 m. **Record the distance each block traveled in the “Metal” column of the data table on the next page.**

12. Click the button to reset the blocks back to their starting positions.

13. The third platform you will be using is **Ice**. Select this platform by clicking on the icon. Hover over each choice until you find ice.

14. Using the pen, drag the ice icon onto the platform.
a) Describe the ice material using three words: ____________________________________________

b) Which of your three blocks do you think will travel the farthest? _____________________________
   Explain why: __________________________________________________________________________

15. Press the button to launch your three objects across the ice platform. Pause the animation as many times as needed.

16. Measure how far each block traveled by using the floor grid as a guide. Each “box” is equal to 1 m. Record the distance each block traveled in the “Ice” column of the data table on the next page.

17. Click the button to reset the blocks back to their starting positions.

18. The fourth platform you will be using is Deflector. Select this platform by clicking on the icon. Hover over each choice until you find deflector.

19. Using the pen, drag the deflector icon onto the platform.
a) Describe the **deflector** material using three words: _________________________________

b) Which of your three blocks do you think will travel the farthest? _____________________
   Explain why: _________________________________

20. Press the button to launch your three objects across the deflector platform. Pause the animation as many times as needed.

21. Measure how far each block traveled by using the floor grid as a guide. Each “box” is equal to 1 m. **Record the distance each block traveled in the “Deflector” column of the data table on the next page.**

22. Click the button to reset the blocks back to their starting positions.

23. The fifth platform you will be using is **Carpet**. Select this platform by clicking on the icon. Hover over each choice until you find carpet.

24. Using the pen, drag the carpet icon onto the platform.
a) Describe the **carpet** material using three words:  

__________________________________________________________

b) Which of your three blocks do you think will travel the farthest?  

__________________________________________________________

c) Explain why:  

__________________________________________________________

25. Press the [button] to launch your three objects across the carpet platform. Pause the animation as many times as needed.

26. Measure how far each block traveled by using the floor grid as a guide. Each “box” is equal to 1 m. **Record the distance each block traveled in the “Carpet” column of the data table on the next page.**

27. Click the [button] to reset the blocks back to their starting positions.

28. The fifth platform you will be using is **Rubber**. Select this platform by clicking on the [icon]. Hover over each choice until you find carpet.

29. Using the pen, drag the rubber icon onto the platform.
a) Describe the **rubber** material using three words: ________________________________

______________________________

b) Which of your three blocks do you think will travel the farthest? ________________________________

c) Explain why: ____________________________________________________________

30. Press the button to launch your three objects across the rubber platform. Pause the animation as many times as needed.

31. Measure how far each block traveled by using the floor grid as a guide. Each “box” is equal to 1 m. **Record the distance each block traveled in the “Rubber” column of the data table.**

**Data Table:** How friction and materials affect an object’s motion

<table>
<thead>
<tr>
<th>Block Material #1:</th>
<th>Distance the Block Traveled (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>_______________</td>
<td>Wood</td>
</tr>
<tr>
<td>Block Material #2:</td>
<td>_______________________________</td>
</tr>
<tr>
<td>Block Material #3:</td>
<td>_______________________________</td>
</tr>
</tbody>
</table>
Part 2: Summary Questions

1. How many of your 6 predictions were correct? Explain your reasoning for why they were correct or incorrect:

2. Which of your three chosen block materials traveled the farthest on all (or most) of the floor materials? 
   ___________________________
   Explain why: ___________________________

3. Which of your three chosen block materials did not travel the farthest on all (or most) of the floor materials? 
   ___________________________
   Explain why: ___________________________

4. State a relationship between the amount of friction between objects and the distance an object can travel 
   ___________________________

5. Which floor material had the most friction 
   ___________________________
   Explain why 

6. Which floor material had the least friction 
   ___________________________
   Explain why 

7. Think of a real-life scenario where you would want to DECREASE the amount of friction between two 
   objects. Explain the scenario and why 

8. Think of a real-life scenario where you would want to INCREASE the amount of friction between two 
   objects. Explain the scenario and why 

9. If you roll a ball down the street and there are no obstacles or objects to block it, why will the ball eventually 
   stop?
<table>
<thead>
<tr>
<th>zSpace Application</th>
<th>Curie’s Elements: The Elements of the Periodic Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lab Title</td>
<td>Using the Periodic Table to Discover Atomic Structures</td>
</tr>
<tr>
<td>Course</td>
<td>Physical Science (7th Grade Students)</td>
</tr>
<tr>
<td>Unit/Topic</td>
<td>Chemistry/Matter</td>
</tr>
<tr>
<td>Time</td>
<td>60 Minutes</td>
</tr>
</tbody>
</table>

**NYS/NGSS Standards**

- **3.3a** All matter is made up of atoms. Atoms are far too small to see with a light microscope.
- **3.3e** The atoms of any one element are different from the atoms of other elements.
- **3.3g** The periodic table is one useful model for classifying elements. The periodic table can be used to predict properties of elements (metals, nonmetals, noble gases).

**NGSS Standards**

- **MS-PS1-1.** Develop models to describe the atomic composition of simple molecules and extended structures.
- **HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

**Rationale & Introduction**

The lab *Using the Periodic Table to Discover Atomic Structures* allows students to learn how to utilize the periodic table to discover the atomic structure of different elements. In a 3D environment, students will be able to understand that atoms are extremely small and are made up of even smaller subatomic particles. Students will be able to recognize how useful the periodic table is when predicting properties of elements and will understand that the atoms of each element differ depending on their properties. Since students cannot visualize atoms in their everyday lives, this lab will offer students the ability to experience these building blocks and manipulate them in ways that change the atomic structure.

**Benefits of Virtual Reality/Haptics**

This lab can be used to pre-teach, teach or re-teach concepts about the periodic table and atomic structure. The benefits of the virtual component is that it is more manipulative and experiential compared to looking at atomic diagrams. Students cannot see atoms under a classroom microscope, therefore this lab allows them to not only see atoms but also rotate them, zoom into them and alter them by adding and removing subatomic particles to create different atoms. The haptic component of this lab provides students with a sense of touch feedback to alert them when they are placing subatomic particles in the correct or incorrect locations of the atom, alerts them when they have clicked on a correct element on the periodic table and allows them to click through detailed views about atoms to learn about their characteristics.

**Recommendations for Classroom Use**

Although this lab can be used to pre-teach, teach or re-teach concepts regarding the periodic table and atomic structure, it is best used as a method of pre-teaching to assist students with independent learning and knowledge construction. Whether or not students have little to no knowledge about the topic, incorporating this lesson into the classroom can show students how to use the periodic table to determine atomic properties of elements. Since this lab is presented in a scaffolded manner, students of all abilities can guide themselves through the lab by following explicit laboratory instructions. Allowing students to make discoveries without teacher guidance can increase their ability to have personal interactions and experiences with new material in order to craft their own knowledge. With a 7th grade population, this lab would be most successful with checkpoint questions throughout the lab so the teacher can formatively assess and monitor student progress. Students should also work in pairs so neither student becomes too dizzy from overstimulation or from the 3D sensor glasses.
How to Open the Program:
1. Click on “zSpace Curie’s Elements” on the desktop
2. A message may pop up saying “you are not connected to a teacher station.” Just click OK
3. Click “Enter Sandbox”
4. You should now see a screen with the periodic table on it
Pre-Activity Questions

Answer the questions based on your knowledge of atoms and the periodic table

1. Define **Atom**: ___________________________________________

2. You are currently looking at the periodic table of elements. Name **three things** you notice about each element just by looking at the periodic table

   a. ___________________________________________
   
   b. ___________________________________________
   
   c. ___________________________________________

Part 1: Periodic Table

*This is the periodic table! Follow the instructions below to work your way through the program. Answer any questions that appear in boxes.*

1. Using the circle button on the pen, click on “C” on the periodic table.

2. When you click it, the element’s name appears underneath

   a. ****What element is this? ____________________________
3. The number on the C tile is the atomic number.

4. The atomic number tells you how many protons and electrons are in the atom

   a. ****How many protons does C have? _____________  
   b. ****How many electrons does C have? _____________ 

5. Using the pen, hover over the C tile and right click on the right rectangular button.
6. Click the button that says “Detailed view.”

7. Use the “>” arrow towards the bottom right hand side of the screen and click through until you find the atomic mass for “C”
8. An element’s **neutrons** can be found by subtracting the **atomic mass – atomic number**. Using the information in the detail screen….

   a. ****What is the atomic mass for C? Round to the nearest tenth! ________________
   b. ****How many neutrons does C have? SHOW WORK BELOW! ________________

9. Let’s Review Part 1:
   a. **Protons** are **positively charged** found in the **center** of the atom called the **nucleus**. They are represented by the **lighter blue circles**
   b. **Neutrons** are **neutrally charged** found in the **center** of the atom called the **nucleus**. They are represented by the **darker blue circles**
   c. **Electrons** are **negatively charged** found in the **orbitals** around the center of the atom (the circles around the atom’s center). They are represented by **yellow circles**.

10. Let’s put our Part 1 knowledge to practice.

    a) Still on the detailed view screen, fill out the chart below for element “C”

    | Element C’s Name: __________ | Where are they found in the atom? | How many in this atom? |
    |-----------------------------|----------------------------------|-----------------------|
    | Proton charge is __________ |                                  |                       |
    | Electron charge is __________ |                                  |                       |
    | Neutron charge is __________ |                                  |                       |

    b) An element has 22 protons. What element is this?
    c) Symbol: __________
    d) Name: ____________________________________________
    e) How did you know how to find your answer to #12? ____________________________________________

    f) An element has 16 electrons. What element is this?
    a) Symbol: __________
    b) Name: ____________________________________________
    g) How did you know how to find your answer to #14? ____________________________________________
Part 2: Practice Questions Using zSpace

Now that you are familiar with the program a little bit, let’s answer some questions. You may need to go to each of the atom’s “detailed view” for these. If you forget how, see the directions below.

- Using the pen, hover over the element’s tile and right click on the right button on the pen
- Click the button on the screen that says “Detailed view.”
- Use the “<” and “>” arrows on bottom right to navigate through the element’s details

Directions: Answer the following questions based on your new knowledge of how to use the periodic table to discover atomic properties.

1. What element is Fe? ______________________
2. What is the atomic number for Fe? __________
3. How many protons does Al have? __________
4. What element is W? ______________________
5. What is the atomic mass for W? ___________
6. How many neutrons does Mn have? _________
7. An element has 79 protons. What element is it?
   a. Symbol: _________
   b. Name:__________________________________________
8. An element has 19 electrons. What element is it?
   a. Symbol: _________
   b. Name:__________________________________________
9. What element has 36 protons, 48 electrons and 36 electrons?
   a. Symbol:_________
   b. Name:__________________________________________
10. What happens to the electron number of an element has as you move across the periodic table? __________
11. Explain the significance of the periodic table _________________________________
12. How is each element unique? ____________________________

__________________________________________
__________________________________________

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13. Using your knowledge and the diagram below:
   a. Label the subatomic particles on the diagram’s lines with the terms proton, neutron or electron.

   (Label the yellow)

   (Label the darker blue)

   (Label the lighter blue)

   b. Using the diagram, what element does the atom above represent?
      • Symbol:________
      • Name:_____________________________

14. Complete the chart below. All answers can be found using the periodic table or by using the “<” and “>” arrows in the detailed view.

<table>
<thead>
<tr>
<th>Element Symbol/Name</th>
<th>Atomic #</th>
<th>Atomic Mass (round to nearest 10th)</th>
<th>Protons</th>
<th>Electrons</th>
<th>Neutrons (Show Work!)</th>
<th>% in Body</th>
<th>% On Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>_____ = _____________</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>_____ = _____________</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>_____ = Zinc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>_____ = _____________</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>_____ = _____________</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>_____ = _____________</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>_____ = _____________</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

15. Explain why it is important to know the element’s atomic mass when determining the atom’s subatomic particle values.
**STOP! GET YOUR CHART AND QUESTIONS CHECKED! **

**Part 3: Building Atoms**
*You will be building 4 simple atoms using the periodic table and the detailed view that you have used in the previous activities.*

1. Complete the **element, protons, electrons and neutrons columns** of the chart below
2. On the home page, click “atom builder” in the lower right-hand corner

3. For each element, click/drag to add protons, electrons & neutrons to the atom using the info from your table

4. When you **think** your atom is correct, click

5. If it says you are **INCORRECT**, edit your atom by **adding** and **removing** your subatomic particles and click again

6. If it says you are **CORRECT**, **draw the atom** in the “ATOMIC DRAWING” column in the chart on the next page

7. To create your next atom, click

   This will reset to a black atom so you can create the next one.
At atomic level, nuclides have different number of protons and neutrons. The table below illustrates the composition of several elements:

<table>
<thead>
<tr>
<th>Element</th>
<th># Protons</th>
<th># Electrons</th>
<th># Neutrons</th>
<th>Atomic Drawing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**STOP! GET YOUR CHART AND QUESTIONS CHECKED! **
Part 4: Summary Questions

1. Write the names for the following elements:
   a. Sc: ____________________________
   b. Pb: ____________________________
   c. Ba: ____________________________
   d. Br: ____________________________
   e. H: ____________________________
   f. Xe: ____________________________

2. The number of protons and the number of electrons is equal to the element’s ________________________

3. The number of neutrons can be found by: __________________________________________________________

4. What element is this?
   a. Symbol: ________
   b. Name: ________________________
   c. Explain how you figured this out: __________________________
      __________________________
      __________________________
      __________________________

5. What happens to the atom when you change its number of subatomic particles? _________________________

6. What can you infer about the atom’s properties when the subatomic particles are changed? ____________

** STOP! GET YOUR CHART AND QUESTIONS CHECKED! **
Chapter Four: Summary and Discussion

Education is a constant attempt to stay ahead of technological trends. Often, the onus is on teachers to come up with creative and innovative ways to engage their students. One of the more popular methods to provide unique instruction to students is through virtual reality. Virtual reality allows students to observe natural phenomena that may be on a micro level or even unobservable in the real world. Often, students are expected to learn concepts that are difficult to replicate in the lab and therefore limits the ability for students to have a hands-on experience when learning new concepts.

A benefit of virtual reality is that it can offer students an experience that is visual, auditory, tactile, safe, realistic and experiential. According to Minogue & Jones (2009), the use of simulations generated by a computer to enhance microworlds is an ideal method to increase active engagement in the classroom when learning complex scientific concepts. With the addition of haptics, which is tactile and kinesthetic feedback, the user’s ability to interact with the virtual environment is enhanced (p. 1359). In addition to the virtual component of these labs, haptics can provide students with force-feedback, which is an excellent way to help students grasp the understanding of phenomena that may otherwise be non-intuitive (Millet, Lécuyer, Burkhardt, Haliyo & Régnier, 2013, p. 608). By implementing these labs in the classroom, it allows the teacher to decrease the time spent on setting up laboratory equipment as well as the need to make sure that equipment is available. In addition to decreasing possible material limitations on the teacher, the virtual reality environment of these labs creates an environment that all students will be able to observe equally.

It is evident that haptic sensory feedback provides students with assistance to determine if their actions are correct. For example, placing electrons in the correct atomic orbital, placing the
nucleus in the correct location of the cell or receiving various magnitudes of force feedback when determining that greater forces causes faster motion. According to Millet et al. (2013), students receiving instruction under haptic conditions had a better understanding of the phenomena than the groups of students that did not receive instruction using haptics. These students also spent more time testing, drawing and answering questions during the simulation (p. 622). The addition of haptic feedback to these virtual labs allow students to not only observe the environments of an atom, a cell, various biomes and other scientific phenomena, but it allows the learners to extend their interactions and communicate with their environment beyond purely auditory and visual means (Wiebe et al., 2009, p. 667). This allows students to spend more time exploring their virtual environment and decrease the possibility of them losing interest in their discoveries.

There will be students in every classroom that may be from a lower socioeconomic status compared to their peers that have not been able to visit other countries, experience wildlife at the zoo, attend a summer enrichment camp or have exposure to tutors to help reinforce information. This could possibly give these students a disadvantage when linking prior knowledge to new knowledge. If students are unable to build off their individual experiences, they will find difficulty in connecting new knowledge to existing knowledge, which can often result in incoherent understanding of scientific concepts (Chao et al., 2016, p. 17). Having virtual simulations available to students can create a learning environment that can cater to various student populations and accommodate several learning styles despite their abilities, language or background. When used in education, virtual reality and gaming creates personal motivation and satisfaction, reinforces skill mastery, accommodates many learning styles and provides a context
for interactive decision-making which helps student develop cognitive skills regardless of possible limitations (Wrezesien & Raya, 2010, p. 179).

When teaching topics that contain intricate understandings within the concept, such as the theory of natural selection or the different types of cell division, teachers will often begin these lessons by teaching the students the concepts in a step by step manner, so they can paint the larger picture at the end of the lesson. However, with many of these broad concepts it can be more beneficial to introduce the bigger picture first, and then break down the details to help understand the concept. These labs can assist in pre-teaching the students about these more abstract ideas, by guiding students through imagery and eliciting skills to help them construct their own knowledge of the concept before they learn the concept more in depth. Not only can this decrease the time needed to be spent on each of these topics in the classroom, but it can allow the teachers to refer to visual examples the students have become familiar with. This increases embodied cognition by placing the importance on connecting prior experience in the virtual world to their physical world when obtaining new knowledge. Granting all students access to the same experiences offers them the same opportunity to construct knowledge and process what they are learning at a deeper level. This can increase their analytic skills and efficacy when answering questions that prompt students to provide explanations as to why things happen, how things happen or make predictions based on possible changes to what they have observed.

Each of these labs are presented in a guided and scaffolded manner. The reason for this is to encourage students to depend more on themselves and their peers and less on the teacher to encourage exploration and problem solving at their own pace. Throughout each lab, students will be asked various questions based on what they are observing and manipulating on their screen so
teachers can formatively assess their understanding as they move through each simulation. At the end of each lab activity, students will be assessed on their overall understanding of the lab by prompting the students to make predictions, create analogies, summarize what they have learned or create and label models and diagrams demonstrating what they have learned. The labs contain a variety of different question styles, such as written response, multiple choice, modeling, graphic organizers and charts to allow students to express their understanding and reflection in a variety of ways.

It is important that teachers properly utilize haptic and virtual simulations so it helps students relate the content being learned to their prior experiences. The goal of these virtual-haptic simulations is that it will allow all students to immerse themselves in the same environment but are able to manipulate their objects differently from one another and have their own individualized experience. Each student explores things differently, therefore these labs can encourage students to tinker and observe their objects in different ways by taking advantage of the proximity that they can reach towards what they are observing. By allowing students to participate in these simulations, it provides students with a visual, auditory and tangible method of learning information in a unique way. Once students can make sense of multimodal representations, they are able to consistently refer to these experiences to enhance future learning (Han & Black, 2011, p. 2289).
References


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