Teaching Middle School Science through Project Based Learning

An Interactive Qualifying Project submitted to the faculty of

Worcester Polytechnic Institute

in partial fulfillment of the requirements for the Degree of Bachelor of Science

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Abstract

The focus on technology is becoming increasingly critical to our society today. In 2013, the Next Generation Science Standards (NGSS) were released. These standards list focused on the importance of how the subjects of science, technology, engineering, and mathematics (STEM) should be taught in a "hands on way" versus with facts and memorization. With this, the goal of the NGSS is to prioritize restructuring pK-12th grade STEM courses, in that it focuses more on career readiness while also tailoring to all different types of students and learning styles. This Interactive Qualifying Project (IQP), "Teaching Middle School Science Through Project Based Learning (PBL)" hopes to adapt the Project Based Learning principals WPI has undertaken, to a middle school setting, while also determining the effectiveness of PBL and the students' attitudes in relation to STEM. This IQP's goal is to formulate lessons in regard to the principals of PBL and determine how effective the correlating project is with incorporating these principals. A major note was during the employment of this IQP, the COVID-19 pandemic was at large and as a result, the PBL unit was deployed in a hybrid classroom environment. To evaluate the PBL unit, an anonymous Pre- and Post-Assessment were administered to the students on the topics of physical forces, such as electric force, gravity, and magnetism. These lessons were implemented in one class, which was further split into two cohorts. It was found that there was a substantial improvement to the students' scores in the two cohorts, with the lesson plans given utilizing group work and activities to demonstrate the topics given, which finally led to the final project of observing a car race. The final race car project designed encouraged students and engaged them to learn and improved their attitudes towards STEM. To learn and obtain a better understanding of how the students felt towards STEM, an anonymous Pre- and Post-Assessment was given at the beginning of the lessons implementations and at the end once all the lessons were completed. It was concluded that the project, which utilized PBL, was valuable for the students and benefited them. The hope for this project is to be utilized and implemented in the future, in classrooms everywhere. With hopes to help the future generations of scientists and engineers become more readily prepared to enter the workforce.

Acknowledgements

This IQP team would like to thank their faculty advisors Dr. Arne Gericke and Ms. Shari Weaver for their valued insight, guidance, feedback, and assistance during the process of creating, executing, and formulating our final paper. We would also like to thank Mrs. DeMaria for welcoming our unit into her classroom and working with us to implement the unit as smoothly as possible.

Introduction and Background

Science, Technology, Engineering and Mathematics (STEM) are now becoming an increasingly integrated part of our everyday lives. While the application of STEM is rapidly evolving, student interest in STEM, including pursuing STEM careers, is dropping according to a poll done by the Institution of Engineering and Technology [8]. The primary issue this Interactive Quality Project (IQP) tackles is the lack of interest in STEM. A starting point in addressing the lack of interest is to investigate how effectively STEM is taught in secondary education and determine how to improve student engagement in STEM. The task of finding innovative STEM educational strategies is becoming more critical in today's society as students must be prepared to fill the rising number of STEM related jobs in this era of technological evolution as reported by the Bureau of Labor Statistics (BLS) [7].

A question then arises, "How do we teach STEM to maximize student engagement?" This is an important question because new advancements and ideas are introduced which come with their own problems that need to be solved with a STEM educated workforce. This has become of sufficient consideration to lead the Bureau of Labor Statistics to state that STEM occupations are expected to "grow about 13 percent between 2012 and 2022. This is faster than the 11-percent rate of growth projected for all occupations over the decade" [7]. Therefore, encouraging STEM participation throughout K-12 education is essential as this demand for a STEM educated population will have to be fulfilled by the next generation.

A nationwide survey done by Microsoft found that most students who major in STEM had made the decision to do so in high school or before. However, according to the same survey conducted by Microsoft [1], only 20% feel as though their pre-college education had prepared them for the STEM field. These findings may speak to the ineffectiveness in how STEM is taught which may contribute to students' lack of interest in STEM. From the findings from Microsoft and IET paired with the growing STEM demand reported by the Bureau of Labor Statistics it can be seen why the lack of student interest in STEM is a problem that must be addressed.

One possible solution is utilizing active learning methods, such as Project Based Learning (PBL). A study done at Jackson State University supports PBL's effectiveness by suggesting that PBL can be used to teach all grade levels and help overcome some common barriers to teaching STEM; poor student preparation, lack of student interest, and a lack of personal connection to STEM [5]. Furthermore, a collaborative research published in the International Journal of Science Education (Vol 27. No. 7) shows that a student's performance in STEM could improve if students are taught using a project-based unit that includes problems with real world context, opportunities for student collaboration, and an option for formulating solutions themselves [9]. Therefore, introducing PBL can be an effective way to increase proficiency in teaching STEM while increasing student interest.

To help understand the effectiveness of PBL and its possibility of stimulating interest in STEM, our IQP group worked with a seventh-grade science teacher from Millbury Jr/Sr High School located in Millbury, Massachusetts. Our IQP group developed, implemented, and evaluated a PBL unit plan on the topic of fields in electric, gravitational, magnetic forces and fields. This allowed us to assess the advantages and disadvantages of PBL as a teaching strategy.

PBL Project Design Elements

In order to understand why PBL is effective at engaging students and raising student interest, the seven fundamental elements of PBL must be understood. Figure 1 is provided below as a reference for the subsequent table, table 1 explaining each element.

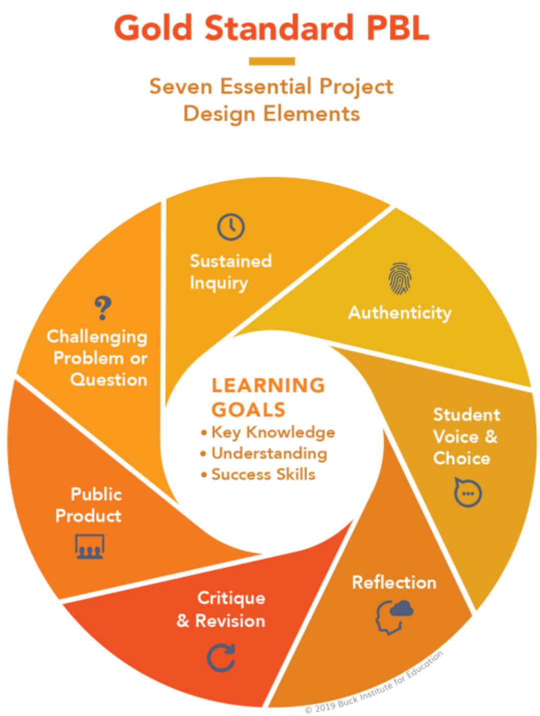

Figure 1: The seven essential design elements starting at "Challenging Problem or Question" that a PBL project must have [2].

Element	**Explanation**
Challenging Problem or Question	The “challenging problem” element serves to provide the basis behind the problem. The project should be framed as a relatable problem to be solved, or a question to be addressed.
Sustained Inquiry	The “sustained inquiry” element is meant to have students engage in a consistent process of asking questions about their problem, utilizing their resources at hand to collect information about their problem, and applying the collected information to answer their generated questions.
Authenticity	“Authenticity” calls for having the project contain some sort of real-world context, impact, or the project appeals to the student’s personal interests, concerns, or beliefs as a method to spark student interest in the project problem.
Student Engagement	“Student engagement” calls for students to determine how they will work to complete the project, how they will convey their final presentation, and be given the ability to do this without constraint.
Reflection	“Reflection” includes student-teacher reflection on how students are learning, the effectiveness of how students are going through their sustained inquiry process, quality of student work, and provide suggestions on how students can overcome the obstacles.
Critique & Revision	“Critique & Revision” is when students will give, receive, and apply their feedback from the teacher to improve their sustained inquiry process, as well as determine the final method on how they decide to present their project
Public Product	“Public Product” is when students can use any method, they would like in presenting their findings throughout the project and publicly present it

Table 1 - Tabulated definitions of each PBL element shown in *figure 1* (adapted from [2])

Overall, in order for a PBL project to be considered a verifiable PBL project, students must be exposed to an overarching problem or question which can be relatable outside of the classroom. The problem or question must force students to enter a sustained inquiry process in which they engage themselves to utilize available resources to solve their problem. Throughout the sustained inquiry process, students will meet with their teacher and receive feedback and guidance on how to complete their project. At the end of the PBL assignments, students are given an opportunity to present their findings in any appropriate way.

To further support the impact of PBL on students, the team researched how applications of PBL have fared in online environments. A study titled "*The Impact of Learner-,Instructor-, and course-level factors on online learning*" delves into the use of project based assignments in an online environment. It is seen that online courses containing project-based assignments which have been paired with higher level knowledge activities have shown a greater learning outcome in students [11]. When analyzing the data from this study, it was found that the project-based assignments had a significant positive impact on the student's final grades. This indicates that if "the proportion of project-based assignments increased by 1% the average final grade would increase by 3.21 points" [11].

Successful projects were identified as containing clear and meaningful goals and instructions with respect to the student's learning objectives. A typical project-based assignment included students being asked to create a multimedia presentation of their own research related to the lesson. The students were given freedom to use any tools they desired in addition to nine options recommended by the teacher [11]. Overall, the study has shown that including a larger variety of project-based assignments can lead to an improvement in final grades, help students who may have special education requirements, and provide more engaging and meaningful gain out of assignments. Despite this study not fully incorporating all elements of PBL, its results corroborate the argument that PBL, even partially implemented, is an effective teaching method.

The study "*The Impact of Learner-,Instructor-, and course-level factors on online learning*" demonstrated that through following even parts of the PBL design elements, students have a higher rate of knowledge retention. Teachers that incorporate PBL units find that students participate more and demonstrate greater interest in the unit. PBL also allows students to relate the topic back to their lives in a meaningful manner. As a result, the IQP team incorporated freedom on how students can present findings, as well as making clear, relatable, deliverables in the final project design. To further support our design process, a second study was analyzed to validate the case that PBL and the previously referenced study were making.

An article titled "*Student Outcomes from High-Quality Project-Based Learning: A Case Study for PBL Works*" investigated the results after implementing a project-based learning program in the classroom. The study was a case study in a high school STEM classroom. The purpose was to implement a project-based learning goal and analyze the outcomes students obtain from the project. This project also followed the Golden Standard Rubric designed by PBLWorks as previously depicted in figure 1.

At the end of the case study, students were asked about their experiences during the project. The highest reported benefit was in regard to students working with a group or team to complete the majority of the project while the lowest reported item of interest was with respect to students engaging in work that connects to personal interests or concerns. This suggests that despite students being able to have freedom in the format of their final project and collaborate on the delivery, it was not personalized learning for everyone [6]. To elaborate, students had the opportunity to deliver their project in any way they chose and presented a project with real world connections. Subsequently, students found the project more enjoyable to work on and found themselves motivated to produce higher quality work, but they did not find the project relevant to their personal interests or concerns. Overall, the study highlighted that when a project fits the PBL Golden Standard project rubric, student learning outcome will be considerably higher as opposed to non-project-based assignments.

Due to the information received from the aforementioned literature, it is believed that incorporating a project-based assignment is the best way to maximize learning outcomes. This project predominantly incorporates a driving question, group work, group discussion, sustained inquiry, and a connection outside of the classroom in order to maintain student interest and knowledge retention which are all core elements in PBL.

Incorporating an effective STEM program into classrooms as shown by previously mentioned literature is a pertinent task that must be explored by the education system. The upward trend of the demand for STEM jobs, and the downward trend of student interest as reported by the BLS, Microsoft, and IET respectively indicate that alternative teaching methods should be explored in hopes to change this current trend. PBL is a valid, alternative method that shows promise for being an efficient teaching strategy as demonstrated through previously cited literature. As a result the IQP team formulated a standards-based PBL unit that will be central to the curriculum, providing an engaging, interactive, but challenging unit for the students. This will provide ample opportunity for students to prove their conclusions freely as well as satisfy the state of Massachusetts STEM Standards.

Massachusetts Science Standards

The upward trend of demand for STEM related professions and the downward trend of student interest in STEM is further supported by decline in college applications, admissions, enrollment rates of -28%, -18%, -6% respectively into STEM programs reported throughout 2003 to 2005 as reported by *Rise Above the Gathering Storm* [10]. Publications that conveyed this evidence played a factor in the formation of the Next Generation Science Standards (NGSS). The NGSS were developed by the states and for the states to adopt. The NGSSs' purpose is to provide secondary education American students a “solid K-12 science education that prepares them for college and careers” [2]. The NGSS committee was inspired to do so because they recognized that STEM is a rapidly evolving field that will be “central to the lives of all American” [2]. The committee recognized that should America maintain its leadership position in the global economy then American students must be given a strong foundation in K-12 studies through methods such as PBL [2]. When the Standards were completed, states had the option to fully or partially adopt the new standards into their curricula.

In the state in which this IQP group conducted their study, Massachusetts chose to realign its curriculum to run parallel with the NGSS. Massachusetts adapted many parts of the standards released by the NGSS. In 2016, Commissioner of Elementary and Secondary Education Mitchell D. Chester, Ed.D. had done this by introducing the *2016 Massachusetts Science and Technology Engineering (STE) Curriculum Framework.* The purpose behind this overhaul was to accomplish a myriad of things, some of which include contributing to student preparedness for post-secondary education, preparing students for “the reality that most careers require some scientific or technical preparation,” and to generally increase their interest in STEM [4]. With the publicity of this, three main emphases arose; rigor, coherence, and relevance. Relevance specifying how lessons should help students with explaining the world around them, rigor calls for inquiry and continuous growth, and coherence calls for students to understand how STEM is intertwined. The three main emphases are a strong part of guaranteeing that the new standards will be effectively conveyed to students and as a result, the revised curriculum provides advice on how to properly engage students and simultaneously acknowledge the three main emphases.

One method that was suggested was employing PBL as a way to “effectively engage students in STE” learning [4]. The reason why the department suggested this is because PBL’s inherent nature of promoting student choice, and voice will promote student engagement [4]. This reasoning addresses issues highlighted in the surveys done by Microsoft and the IET. Further justification for suggesting PBL includes the incorporation of student revision and reflection which requires students to provide and receive instructor feedback. In addition, PBL allows for student reflection on their own cognition and understanding of the topic which in turn, satisfies the rigor requirement.

Another reason why PBL was a suggested method to convey these STE standards is because PBL requires students to reference multiple domains when addressing their assigned standard. When learning multiple domains for one standard, students begin seeing how multiple disciplines come together to produce the phenomena that a standard may cover when multiple disciplines are incorporated into addressing a standard. PBL’s inherent nature to use multiple disciplines of related topics to teach a unit, directly aligns with the coherence requirement set by the new STE standards, which allows for students “learning the fundamental concepts of each domain in STE, as well as the connections across those domains.” [4].

Although not directly mentioned in the revised framework, one of the critical elements of PBL as stated by a study done to explore the five main criteria of PBL is that "projects are realistic" [11]. This means students should be able to relate their project to some sort of real world application that directly affects them or their society. The final emphasis of relevance as highlighted by the revised framework becomes fully addressed when teaching through PBL.

When meeting with Mrs. DeMaria, the aforementioned teacher from Milbury Sr/Jr. Highschool, she mentioned she had incorporated active learning strategies, including PBL into her classroom before. She discussed with us her previous experience with incorporating PBL and demonstrated her belief in PBL being an effective teaching strategy. The conversation eventually led to her difficulty in finding an appropriate unit for certain standards. She then provided us with the standards she found most difficult to employ from the *2016 Massachusetts Science and Technology Engineering (STE) Curriculum Framework* and are pictured below, in *Figure 2* and *Figure 3*.

7.MS-PS2-3. Analyze data to describe the effect of distance and magnitude of electric charge on the strength of electric forces.

Clarification Statement:

- Includes both attractive and repulsive forces.

State Assessment Boundaries:

- State assessment will be limited to proportional reasoning.
- Calculations using Coulomb's law or interactions of sub-atomic particles are not expected in state assessment.

Figure 2. Massachusetts State Standard for electric charges **[4]**

7.MS-PS2-5. Use scientific evidence to argue that fields exist between objects with mass, between magnetic objects, and between electrically charged objects that exert force on each other even though the objects are not in contact.

Clarification Statement:

- Emphasis is on evidence that demonstrates the existence of fields, limited to gravitational, electric, and magnetic fields.

State Assessment Boundary:

- Calculations of force are not expected in state assessment.

Figure 3. Massachusetts State Standard for the existence of gravitational, magnetic, and electric fields. **[4]**

Reviewing the standards and discussing with Mrs. DeMaria illustrated the challenges she faces when trying to implement the standard into the classroom. She stated that it was difficult to find activities and assignments that could clearly convey the material, while also simultaneously engaging the students. From the aforementioned evidence it is suggested that PBL may be the solution to this obstacle.

In order to overcome disinterest and the struggle of conveying knowledge to the students, a project was designed to address all aspects entailed by the previously listed standards. As a result, a PBL unit was specifically employed to further student understanding of magnetic, gravitational, and electrical fields as noted in figures 2, and 3 respectively. However, there is much more general benefit to delivering the lesson in the form of PBL. It provides an opportunity to fulfill the state guidelines for STEM while also focusing the student's attention to delve deeper in the workings of the fields previously mentioned. This in turn, allows the students to critically think and understand the "why it works" and the "how it works" of the given topic. As supported by the collaborative research done in the International Journal of Science Education (Vol 27. No. 7) [9], the PBL assignment is able to: promote a broad goal of achieving a higher retention rate for STEM knowledge, promote critical thinking from a sustained inquiry, and build communication and presentation skills through student discussion and presentation.

Ensuring the PBL Criteria is being Incorporated into the Project Design

The purpose of the project is to increase student interest in STEM and through the evidence provided, demonstrating that PBL may be a valid approach in doing so. As a result, the 7 essential designs shown in *Figure 1* and tabulated in *Table 1* were all incorporated into the overall project. However, due to time constraints, topics based on the fundamental fields of magnetism, electricity, and gravity were all assigned as hands-on learning activities prior to the final cumulative project which includes the previously mentioned fields. In all hands-on learning activities, student attention and interest is gained through a thought provoking question, followed by a discussion amongst themselves, and finally an interactive activity used to demonstrate how the specific field works in real life.

The cumulative project addresses all elements shown in *figure 1* through a scenario. In which the students were engineers designing an optimal race car. Students experimented with varying weights, magnetic, and electromagnetic strengths on race cars to see which set up resulted in the fastest car. This allowed students to visually and verbally explain how fields of different sources exist and are able to work together to produce a relatable result. Simultaneously students will understand the relationship of positive and negative charges due to how the race cars are being powered. In the final parts of the project, students must determine real world applications of the fields they are experimenting with as well as present their findings in any appropriate method.

To further ensure that the project our IQP designed is considered PBL, we referenced a study done by *John W. Thomas, Ph. D*. This study explored the five criteria that must be met to be considered a PBL, as stated by *John W. Thomas, Ph. D* who investigated the criteria under the support of The Autodesk Foundation. The first criterion is that “PBL projects are central, not peripheral to the curriculum” [11]. With regards to this project, this entails that the students will be learning the concepts and applications of magnetic, electric, and gravitational fields along with positive and negative charges throughout their race car project as opposed to the project simply being an addition to the standard. Dr. Thomas also calls for, “PBL projects [to be] focused on questions or problems that ‘drive’ students to encounter (and struggle with) the central concepts and principles of a discipline” [11]. This is usually accomplished through a question or problem [11]. We have centralized our PBL across the problem of what variation of magnets and weights will provide the fastest car. This question requires the students to explore many possibilities amongst themselves and provide explanations and supporting evidence before a final answer can be shared.

Dr. Thomas also requires that all PBL are, “projects [...that...] involve students in a constructive investigation” [11]. To elaborate, students must be asking questions, finding answers themselves, and coming to a conclusion. Through the driving problem of the project, a sustained inquiry is called for which students must investigate different possible answers, evaluate and conclude with justifying statements. This ties into the fourth criterion for PBL, “Projects are student-driven to some significant degree” [11]. PBL projects “incorporate a good deal more student autonomy, choice, unsupervised work time, and responsibility…” [11]. This means students go through their sustained inquiry and discussion primarily among themselves. Students are also required to research topics, recollect previous knowledge, and the final result of their project is not solely one predetermined outcome. A student being able to appropriately justify their outcome using evidence and knowledge gained through the project and hands-on activities is satisfactory.

The final criterion for PBL is that “projects are realistic, not school-like” [11]. This requires a project to make students feel as though their effort relates to something beyond the classroom. Students must clearly see some sort of personal or societal impact. With the specific scenario for Mrs. DeMaria’s class, the students are being tasked as an engineer with the goal of optimizing a race car. The ability for a student to see the impact beyond the classroom shouldn’t be difficult with this context. Vehicles are omnipresent in society. Many students get to school using vehicles which means that students should be able to recognize the impact of this project beyond the classroom. Overall, the PBL project that the IQP team has created fulfills all PBL criteria and provides an authentic context to the students of Millbury Jr. High School.

The Goal

The state of Massachusetts recognized that there is a need for improved STEM education in the state, citing its importance in everyday life regardless of profession, lifestyle, or location in the world. STEM is necessary when; making informed decisions about one's health, supporting any type of infrastructure development, understanding the basis behind STEM based public debate, etc. [4]. Due to this Massachusetts updated the STEM Curriculum to become the *2016 Science and Technology/Engineering (STE) Framework* which emphasizes the need for a framework that provides relevance, rigor, coherence and engagement to students [4]. These topics allow for students to see the relevance of STEM more clearly, learn to apply knowledge to resolve sustained inquiry, learn how to combine different aspects of STEM to come to a viable conclusion, and be given the opportunity to be in an environment where interest in STEM can be fostered. This basis set by Massachusetts is an important one, however there is more that can be done to further student comprehension and interest in STEM. This has been demonstrated by PBL increasing student interest in the STEM topic at hand, enjoyment of the PBL assignment, and greater knowledge retention as previously described. Subsequently, the aim of this project is to take the STE standards and integrate a PBL experience for the class which will overcome the barriers of low student interest, comprehension, and retention while simultaneously influencing a student's viewpoint on STEM in a positive light.

The specific unit plan for the PBL will be deployed over the course of two weeks and are designed to encourage students to learn about the existence of gravitational, magnetic, and electric fields, as well as the existence of charges as stated by the Massachusetts STE Standards MS-PS2-3 and MS-PS2-5 [4]. A special challenge that the IQP team will face is that the IQP unit will be deployed in a hybrid classroom environment due to the COVID-19 pandemic. To successfully do this, the IQP team provided Mrs. DeMaria with interactive activities, worksheets, quizzes, and interactive online laboratories to provide basic information while incorporating some aspects of PBL. The classroom material that will be provided is set up in such a manner so incorporation into a hybrid environment is done smoothly. Following this, the IQP team created and shared with Mrs. DeMaria a PBL activity that incorporates both standards and the supplementary information that was provided. To gauge how effective the project and supplementary materials were, assessment surveys, pre- and post- surveys were employed along with brief quizzes on the topics discussed with students. The team then plans to optimize the unit based upon feedback from quizzes, and all surveys so the project can be used more efficiently in the future.

The Project

After reviewing the STE standards in depth and formulating ideas, the IQP team came to the conclusion that the final project must incorporate aspects of both standards at once in a unique fashion. The central project must contain aspects of gravitational, magnetic, and electric fields paired with the incorporation of electric charges. The team was aiming to design a two-week unit with this information, then later came to the conclusion that the students will be taught the basics of gravitational, magnetic, and electric fields and the basics of electric charges through hands-on activities. The general structure of the supplemental hands-on activities would include an opening question for the students, followed by a brief explanation of the topic, and an interactive project which will allow for students to continue the inquiry beyond the initial topic. Concluding the class, students will take guided notes on a lecture and complete online laboratories, quizzes, and worksheets to supplement their knowledge. The students will be made aware that their written notes and responses will become useful information later when they go on to design an optimal vehicle. Once students have been given the basic information, they'll be presented with the final project which is centralized around determining an optimal race car design from running experiments with two different types of race cars. One set of cars will have varying weights and magnet strengths on them, the other will have varying electromagnet strengths on them.

Students will have to propel these vehicles using magnets and take note of performance based on weight, magnet strength, and electromagnet strength. At the end of the race, students are tasked with the sustained inquiry of determining what variation of weights, magnets/electromagnets prove to be the fastest car. In order for students to successfully find an answer to this problem, they must reflect on the results of all races, determine why the results were what they were, then provide an explanation on why they feel their decision is the most optimal set up.

To further enhance the sustained inquiry and continue critical thinking, students must come up with a way to relate a real-life application of the fields, bullet trains, to further optimize their own race cars. Due to the open-ended nature of this part of the project, students will be able to reflect on what they know, share their ideas with others in a healthy critique and revision session, then produce and publicly present a possible way to innovate their already optimized race car as well as further real-world applications of the fields in use. PBL has shown promise in keeping students engaged, proactive, and interested in STEM. This project was designed with this in mind and the project was finalized and sent out for Mrs. DeMaria to implement.

Methodology

Initial Project Formulation

Our advisor, Professor Shari Weaver, connected us with a teacher willing to incorporate a PBL unit into their classroom. This teacher, Mrs. DeMaria, asked us to design a PBL unit which covers Massachusetts state standards MS-PS2-5 and MS-PS2-3 which involved the following:

1. Students must understand how magnetic, gravitational, and electrical fields work.
2. Students must understand how these fields can impose forces without physical contact.
3. Students must understand how these fields can impose forces that change with distance.

The teacher told us that she had no specific requirements aside from fulfilling the state standards. We brainstormed unit ideas with the central requirement that our project must be focused around the use of magnetic, electric, and gravitational fields without physical contact. This central requirement would satisfy the standards shown in figure 1 and would be able to be adjusted to satisfy PBL requirements.

The best project idea formulated to accommodate the standards in figure 1 as well as the PBL design elements was to have a project which utilized the three fields in a race. Students were tasked to design race cars which had a variation of magnets and weights, or electromagnets and weights. The purpose behind the design was to incorporate their knowledge on the respective fields and design the fastest car. To evaluate their design, the students then had to race the cars without touching them during the race. This was decided to be accomplished by students taking advantage of magnetic poles working with electrical fields in the electromagnet cars and capitalizing on the magnetic fields emitted by the magnetic cars. The varying weights were put on the cars as a way to slow them down through inertia forces.

In order to ensure that the project met the PBL standards the following PBL criteria tabulated below in figure 4 were reviewed and incorporated into the final project.

Criteria	**Method of Incorporation**
Challenging Problem or Question	Students have determined the most optimal set up to yield the fastest car. Students are also asked about alternative setups and their viability.
Sustained Inquiry	Students have continuously run trials, collected data, and referred back to their

	previous activities and lessons to understand their collected data.
Authenticity	The problem involved optimizing vehicles. Due to how essential cars are, every student has clearly seen the impact of vehicles in the real world beyond the scope of the project. Students were also tasked to investigate how the fields at play can be used to benefit other aspects in life.
Student Engagement	Students collaborated to solve the problems presented and formulated their own ways on how to present their findings.
Reflection	Students scheduled meetings with the teacher as an outlet for feedback on current work and received feedback to improve the efficiency of the student's inquiry process.
Critique & Revision	Students have taken and applied the knowledge gained from the reflection process. Upon completion, students brought their final findings to Mrs. DeMaria and hypothesized ways to present their final project.
Public Product	Students presented their work in any method they feel comfortable in.

Figure 4: A table of the PBL design elements paired with how the IQP team's project will fulfill each element throughout the project.

As shown in figure 4, the IQP group's project idea fulfilled all seven design elements called for by PBL [3] and fulfilled the Massachusetts STE standards given to us by the teacher. Moving forward, we incorporated methods to measure the study's effectiveness. It was decided that before this project was to be incorporated into the classroom, students must be taught basic information on the fields. It was also determined that pre and post aptitude and attitude tests for the topics being covered must also be implemented before teaching to help gauge PBL's effectiveness. However, we had to consider that there was a limited number of days to present this to the classroom, and each day had only a small cohort of the total class in person with the remainder being online due to COVID restrictions.

Due to these constraints, it was decided that there must be dedicated days to learning and understanding the qualitative characteristics of each field. When the cohorts were physically in class they were exposed to a brief discussion, an activity paired with a worksheet, a short lecture with guided notes, and a take home assessment of some sort. This was repeated for each field to be taught. This setup ensured that every student had the necessary knowledge prior to completing the final project.

Logistics

As COVID-19's effect on the world was still current at the time of the study, safety restrictions were put in place to help control the spread of the virus. Therefore, the school had made the decision to split their students into two cohorts. The cohorts that this team will be working with will be labeled as cohorts "A" and "B". The following cohorts experienced a hybridized schedule of which each cohort met with the teacher in person for two days of the week and then completed the remaining week online.

Class	**Monday 2/22**	**Tuesday, 2/23**		**Wednesday, 2/24**	Class	**Thursday, 2/25**	**Friday, 2/26**
C Block, Cohort A (in person)	Paperclip/Magnet Activity	Electricity Guided Notes & Worksheet	C Block, all cohorts	Magnetism Guided Notes & Activity 1	C Block, Cohort A (remote)	Magnetism Activities (Phet Simulation)	Magnetism Activities (Phet Simulation)
C Block, Cohort B(remote)	Electricity Guided Notes & Worksheet	Electricity Phet Simulation and Worksheet			C Block, Cohort B(in person)	Paperclip/Magnet Activity	Magnetism Activities (Phet Simulation)
D Block, Cohort A (in person)	Paperclip/Magnet Activity	Electricity Guided Notes & Worksheet	D Block, All cohorts	Magnetism Guided Notes & Activity 1	D Block, Cohort A (remote)	Magnetism Activities (Phet Simulation)	Magnetism Activities (Phet Simulation)
D Block, Cohort B (remote)	Electricity Guided Notes & Worksheet	Electricity Phet Simulation and Worksheet			D Block, Cohort B (in person)	Paperclip/Magnet Activity	Magnetism Activities (Phet Simulation)

Figure 5: A visual depiction of the classroom schedule for week 1.

Class	Monday, 3/1	Tuesday, 3/2		Wednesday, 3/3	Class	Thursday, 3/4	Friday, 3/5
C Block, Cohort A (in person)	Complete Magnet/Compass Online Phet Activity; Electromagnet Lab	Electromagnet Lab	C Block, all cohorts	Introduce Project	C Block, Cohort A (remote)	Electromagnets and Force Online Simulation	Electromagnets and Force Online Simulation
C Block, Cohort B(remote)	Electromagnets and Force Online Simulation	Electromagnets and Force Online Simulation			C Block, Cohort B(in person)	Electromagnet Lab	Electromagnet Lab
D Block, Cohort A (in person)	Complete Magnet/Compass Online Phet Activity; Electromagnet Lab	Electromagnet Lab	D Block, All cohorts	Introduce Project	D Block, Cohort A (remote)	Electromagnets and Force Online Simulation	Electromagnets and Force Online Simulation
D Block, Cohort B (remote)					D Block, Cohort B (in person)	Electromagnets and Force Online Simulation	Electromagnet Lab

Figure 6: A visual depiction of the classroom schedule for week 2.

Cohort "A" met in person on Monday and Tuesday, while cohort "B" met in person on Thursday and Friday. On Wednesday both cohorts met online. The two standards given were taught over two weeks and the prerequisite lessons, on the fundamentals of the three fields, were taught prior to the project being presented.

As depicted in Figures 5 & 6 For the first week the students were taught course material associated with magnetism and electricity. In the second week, students completed the magnetism and electricity topics, and Wednesday of that week marked the start of the project. Finally, Thursday and Friday were reserved for completing material associated with electromagnets.

Turning Ideas into Material

Surveys

The week before the lessons began, the teacher administered an online STEM aptitude survey found in appendix E3. This survey was designed to let the team get a basic idea of how knowledgeable the students were with the topics as well as gauge their personal interest in STEM prior to the students completing any work. PBL’s goal is to increase student interest and learning for the topics presented. The results of these surveys allowed us to quantitatively, and qualitatively measure any changes in applicable STEM aptitude. Through data collected from these surveys, we will have gained solid evidence pointing towards the effectiveness of PBL in this environment.

Another survey found in appendix E2 was given. This survey focused on the attitude the students held towards the topics and subject being taught. Similarly, this survey was vital as it allowed the team to qualitatively measure how the students felt about the topics before and after the materials have been given. The team also hoped that the evidence obtained from said survey would have helped PBL’s effectiveness.

Electrical Fields

The intention for this topic was to show how electricity can generate fields that create a resulting force, as well as demonstrate how these fields can interact with one another. When the teacher first introduced this topic, they followed the electricity lesson plan in appendix B3. The teacher started class with a discussion about electric fields as detailed in part 3 of the lesson plan in Appendix B3. This discussion served to have students begin thinking about what phenomena electrical fields are responsible for. Followed by this discussion, students will have received a handout found in appendix D3b which had two parts. The first part required students to have answered questions which led up to the following in-class activity. The second part of the worksheet was relevant to a lecture introduced later on in class. After students completed the first part of the worksheet, students then completed the activity described in stage 3 of the lesson plan in appendix B3. The activity allowed students to experience the electrical fields in action through attempts to stick a balloon against their chests. This activity should serve as evidence that attractive forces exist as implied from the previous handout Appendix D3b.

Following, the teacher introduced the lecture in appendix D3a to help further explain the physical phenomena that was demonstrated in the activity. The lecture went further into the topics of electrical charges, associated vocabulary, and field behavior. Students were also encouraged to follow along with a guided notes handout found in appendix D3b. The guided notes served to help reinforce lecture knowledge as well as for students to reference when completing their final project.

The lecture concluded with students being asked a challenging question for the final portion of the lecture in appendix D3a. The question called on students to recollect lecture material and hypothesize ways to impose contactless force with electrical fields. To aid in answering the question, the teacher should have helped guide the students with information presented previously in lecture. In the event that the teacher was not able to physically demonstrate the solution in the class a video was embedded into the lecture material shown in appendix D3a for virtual student access. To conclude, a quiz found in appendix C3 was given to check on how well the students understood the topic that was taught. The teacher should have had the student complete the quiz at home and was graded based on accuracy.

Magnetic Fields

The first part of the topic was to initiate a discussion as called for in the magnetism lesson plan found in appendix B2. The purpose of this discussion was to have students think about what phenomena magnetic fields are responsible for. Following this the students were then tasked with an activity dictated in stage 3 of the lesson plan found in appendix B2. Students were asked to push a magnet off of a table without touching said magnet by using another magnet. This was done for students to acknowledge the existence and behavior of magnetic fields.

Following this, the teacher presented the lecture about magnetism found in appendix D2a. The lecture discussed relevant vocabulary, explained the poles of a magnet, the basic workings behind attractive and repulsive forces, as well as how magnetic fields can interact with each other, and other forces such as electricity to form electromagnets. Students were encouraged to take guided notes found under the second section of the handout in appendix D2b. The guided notes were assigned to ensure that students can later recall the material discussed from the lecture, serve as a reference point for completing the final project, and take-home assignments.

At the end of the lecture, a more complex question was presented to the class. Students were given the question of how to create an electromagnet. This question served to set up background knowledge that is beneficial for the project. Students were then sent home to complete the correlating quiz found in appendix C2 as well as an online simulation paired with a worksheet found in appendix D2c. The quiz indicated the student's comprehension of the topic given. The online simulation helped students understand what factors can affect the strength of an electromagnet and further developed their understanding of an electromagnet's association with magnetic fields. The quiz was graded based on how accurate the student responses were to what was discussed in class.

Gravitational Fields

The purpose of this topic was to ensure that students were able to recognize that gravitational fields impose force upon an object from an object of a larger mass that is within a said distance of the smaller object. As by the lesson plan in appendix B1, the class started with a discussion about why a ball fell to the ground when released. The teacher guided the discussion to the answer of gravity so students can begin to acknowledge the existence of gravity in this demonstration. Once the discussion is complete, the teacher then introduced the paperclip & magnet activity found in appendix D1c. Students followed handout instructions in appendix D1c as well as watched the teacher guide the activity. The activity involved varying magnetic strengths overcoming the force of gravity on paper clips. The purpose behind the varying magnetic strengths was to show that the greater the magnetic force, which is the force against gravity in this activity, the more distance the paperclip can have between itself and the magnet while simultaneously being attracted to the magnet.

Following the in-class activity, students were then asked to pull out their guided notes in appendix D1b to take notes on a lecture in appendix D1a. The lecture had gone over relevant vocabulary and magnetic field behavior. The lecture also included a video embedded to further clarify how gravitational fields work as well as clarify any confusion amongst students. Students were then sent home to complete the worksheet found at the bottom of the paperclip & magnet handout in appendix D1c. The worksheet fulfilled state standards due to its inquiry on how gravity imposes forces upon objects without contact, and also incorporated part of PBL's design elements due to students being required to relate what they have learned to the real world in the worksheet found in appendix D1c.

Implementing the Project

Once students have obtained all the necessary knowledge to complete the project, the final topic was the project itself. The class began with students reviewing the project handout found in appendix D4a as well as the project rubric in appendix D4b. The teacher provided a verbal explanation of how each race was going to happen followed by a demonstration. Detailed student instructions can be found in Appendix D4a and detailed teacher instructions are found in the learning plan section of the document appearing in appendix B4. Once students had an understanding of what to do, students then ran through each race taking notes on each car's performance as well as any reasons they think why a car performed the way it did.

After the first race, the teacher paused the class for a class discussion on why students think each car performed the way it did in each race. The teacher guided responses to include key vocabulary phrases mentioned in previous days such as: "magnetic field," "attracting/repelling," etc. The process was repeated for the second race and at the very end of the activity the teacher asked the class to explain the reason behind the race outcome as well as why the vehicles were able to be propelled without physical contact.

Following this discussion, students began working on their take home portion of the project in appendix D4a which required students to discuss the results of races and how they relate back to the fields that they have learned over the past few days. To delve further into the project and enhance sustained inquiry, students were required to investigate multiple applications of the fields in today's society. Throughout the take home portion of the project, the teacher should have ensured that students have scheduled review, critique, and revision sessions, as well as seek feedback from the teacher to ensure that they are on the right path.

The main objective of this project was for students to understand that inertia was one of the reasons why the weighted race cars were slower when repelled or attracted by the magnet placed into the car's magnetic field's range. Students should have also recognized that there was a distance in which the electrical and magnetic fields had an effect for the electromagnet race. Students should have acknowledged that the greater the distance between the two fields equated to a lesser force being imposed.

Observations & Implementation

Due to COVID restrictions the IQP team was unable to physically be present for when the unit plan was deployed. As a result, an engagement form was developed for the teacher to fill out after every topic found in appendix E1. The form asks the teacher to gauge student performance and engagement on a set scale as well as through open ended questions. Performance relates to how well students score on graded assignments, and student engagement relates to how well students became interested in the topic as well as the degree of participation.

Please rate the comprehension, participation, attentiveness, engagement, and success rate on a scale of 1-5.

1 - Little to nothing
2 - Minimal
3 - Some / average
4 - Greater than average
5 - Exceeding average

Figure 7 The number scale for when asked to rate student interaction in various instances on the engagement form (Appendix E1**)**.

From Figure 7 the definition behind numerical ratings was presented. The rating scale allowed us to determine the success rate behind each assignment when supplemented with instructor feedback on how the class went. A consistent trend to be noted is that online students showed a low completion rate for assigned work however when students completed their work, they received grades which were much higher than the total average regardless of if they were virtual or not.

Results and Analysis

This project managed to demonstrate the given standards to a given class of seventh grade students. The students were able to observe and learn about different forces caused by the different fields of electricity, gravity, and magnetism. A final project, centered around the principals of PBL, was given in which students were able to observe multiple forces interacting with one another, as well as practice how to collect and observe data from a given experiment. With a prior meeting with the designated teacher, speaking about how prior units were implemented while also satisfying the Massachusetts science standard, the teacher has formulated her thoughts and opinions about PBL and its effect on the students.

Due to the unique circumstances surrounding the health and safety guidelines regarding the pandemic, there were many challenges associated with the project stated. With how the given school operates under the current circumstances, students were left to complete online work when their given cohort was not required to be in school. Complications arose as some students chose either to not complete or to not attempt the online assignments given. This impacted the results, as when accounting only for the students who completed the given assignments, the average tended to be higher than the overall average for the assignments from the entire class.

In regards to the final project given, the race car project, the given racecar that was designated to show the effects of an electromagnet was scrapped as there were complications related to securing the electromagnet to the car. This resulted in only two out of the three cars being made and raced against each other. The time constraint also affected one of the main aspects of PBL, as for the project assigned for the students to complete in conjunction to the race car project, was not able to be completed with its original intended purpose of allowing the students free will of how they wish to express their results. The students instead were given a rubric of which they were directed to follow in order to present their final project. As seen in Appendix D4b, the final projects were created following the given rubric, with the average being 67.5% between all of the students. Many students enjoyed the project and were engaged with data collection and problem solving. However, when it pertained to connecting the race car project to the real-world example given, many students struggled. All the students were able to complete the final project to some degree and most students concluded that out of the three cars constructed, the basic car traveled the most distance over the shortest amount of time as there was presumed to be less friction. Students also showed understanding that there exists a relationship between mass and gravitational force as they were able to use the data collect as evidence to prove that the car that had more "weight" traveled the shortest distance over the given time, as seen in Appendix G.

Surveys

A pre and post knowledge and attitude survey were given to obtain a general understanding of what the student's understood prior to the unit formulated. Both surveys were to be completed anonymously and both were to be given before and after the given unit. All the questions stayed the same.

Pre and Post Knowledge Assessment

To obtain a baseline understanding of what the student understood before the given lesson plans were done, a pre and post knowledge assessment was conducted.
For the knowledge assessment the following questions were asked:

1. What is electricity and what gives it its charge?
2. Select everything that Electrical fields can do
3. In terms of electricity, what is attraction and repulsion?
4. How do magnets attract of repel objects without touching them?
5. What do you call the area that magnetic force exists in?
6. In your own words, describe how attraction and repulsion work in magnets?
7. In your own words, describe what gravity is
8. Why do we land back on the ground when we jump
9. How does distance relate to gravity (Read carefully!)
10. Why do you think that when you jump on the moon, you can jump higher than what you could jump on earth?

The students' following responses:

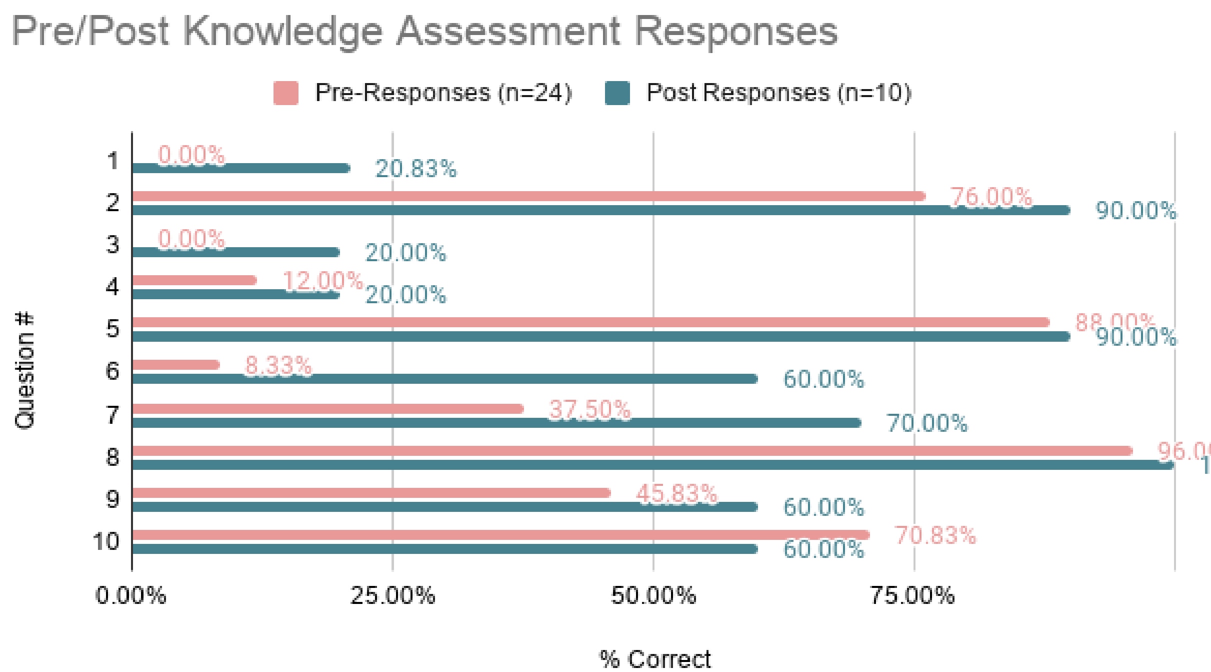

Figure 8: The following is a graph with only the pre-assessment knowledge responses given for the Pre/Post Knowledge Assessment

Pre and Post Attitude Survey

To obtain more data of how the students felt about STEM, a pre and post attitude assessment was also given.

For the attitude assessment the following questions were asked:

1. Do you like Science
2. If you answered yes, please explain why
3. If you answered no, please explain why
4. Do you think we use science daily
5. What do you think your strong points are academically? (i.e.: science, math, reading, writing, etc.)

6.	What do you think would make you more confident in terms of being able to understand the material better?
7.	How confident are you when it comes to learning new things?
8.	How well do you think you understood the material given? (Answer, “TBD” if the new lesson plan has yet to be given

The following student’s responses:

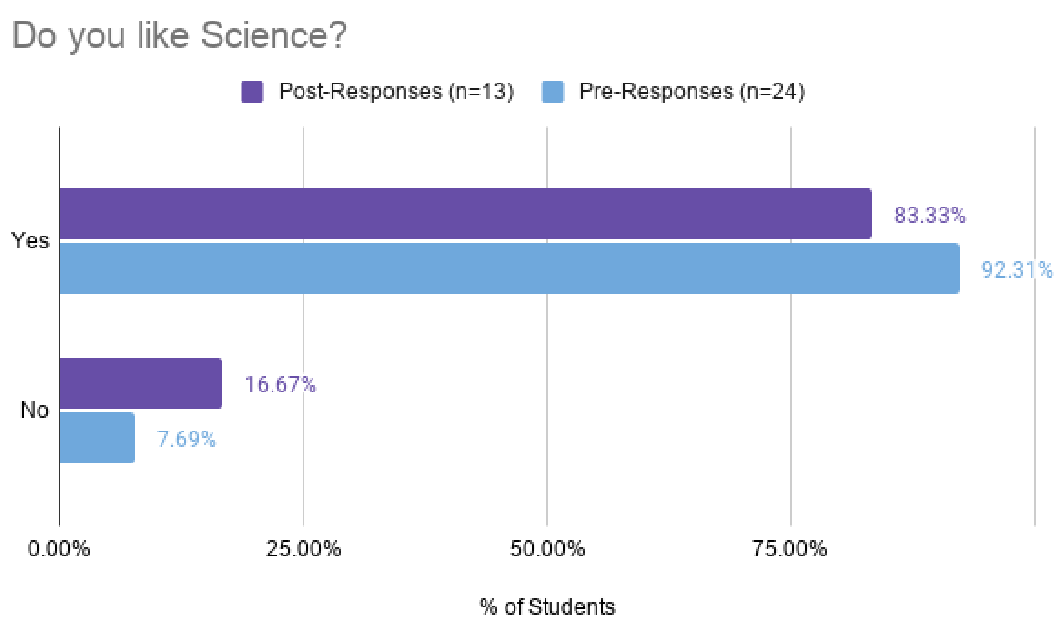

Figure 9: The following student’s responses in relation to question 1 on the pre/post attitude survey.

The most common answer for question two in both the pre and post assessment were, “Experiments are fun” and, “Interested in everyday Phenomena” for the students that replied yes. Conversely for the pre-assessment, “Not Interesting” and, “Too much work” were the most common answers for the students that replied no. For the post-assessment the most common answer was, “I've nether really been into science and all the things we learn in science”.

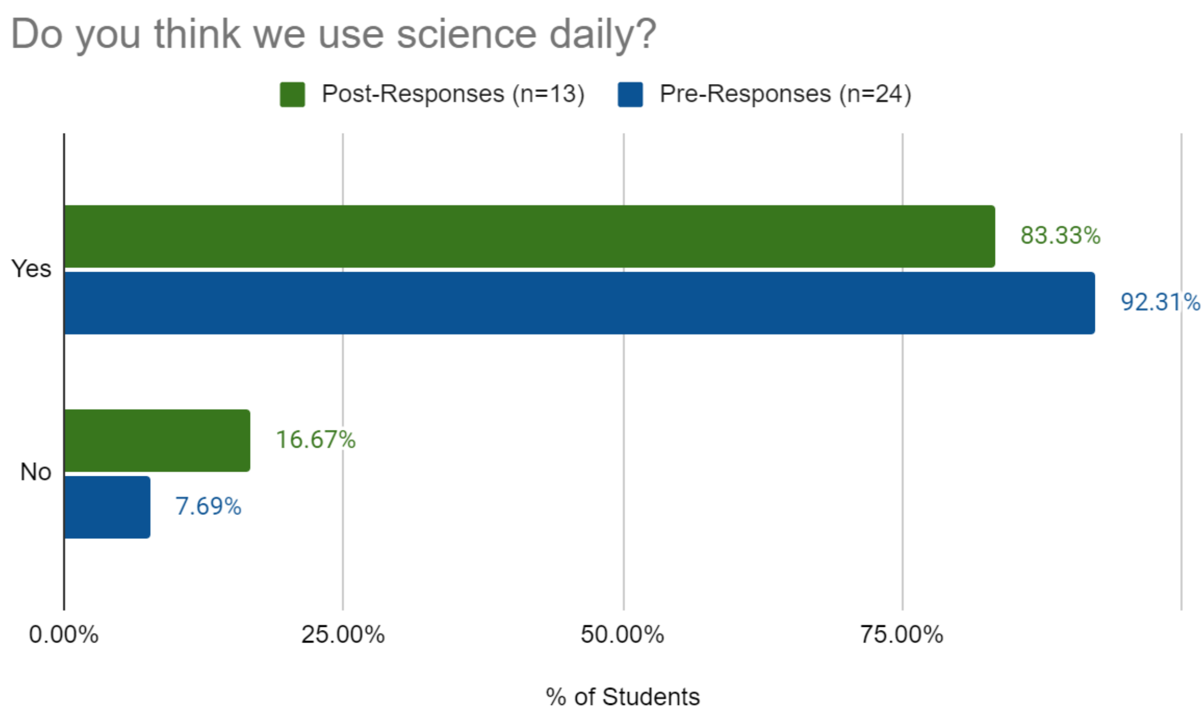

Figure 10: The following student's responses in relation to question 4 on the pre/post attitude survey.

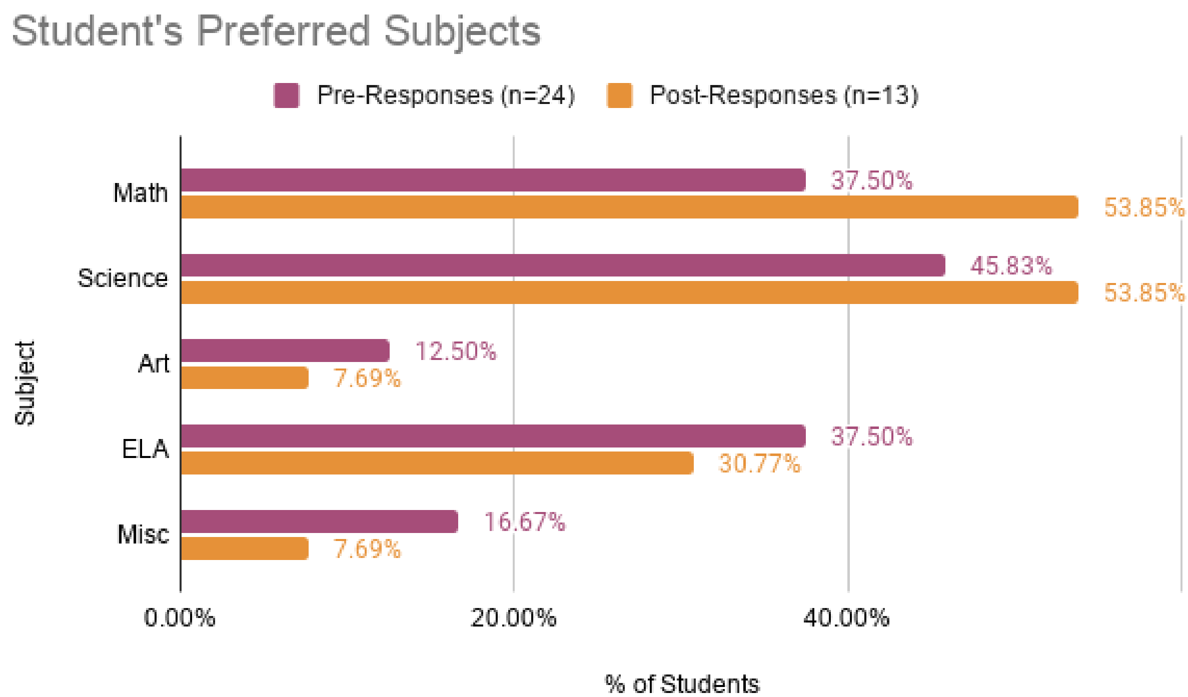

Figure 11: The following student's responses in relation to question 5 on the pre/post attitude survey.

The most common answers for question six for the pre-assessment was either, "I don't know" or, "Going Slower". While the most common answer for the post-assessment was "I don't know" and "more help with teachers".

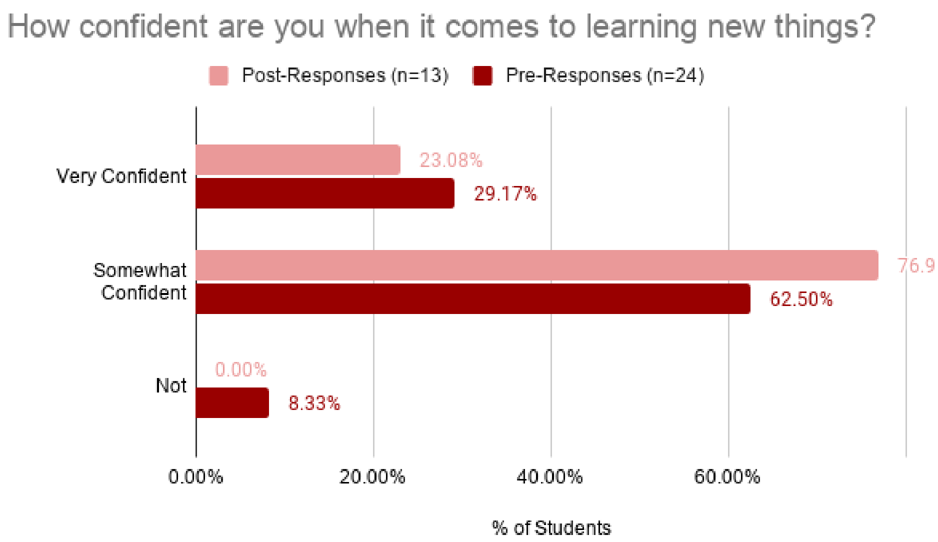

Figure 12: The following student's responses in relation to question 7 on the pre/post attitude survey.

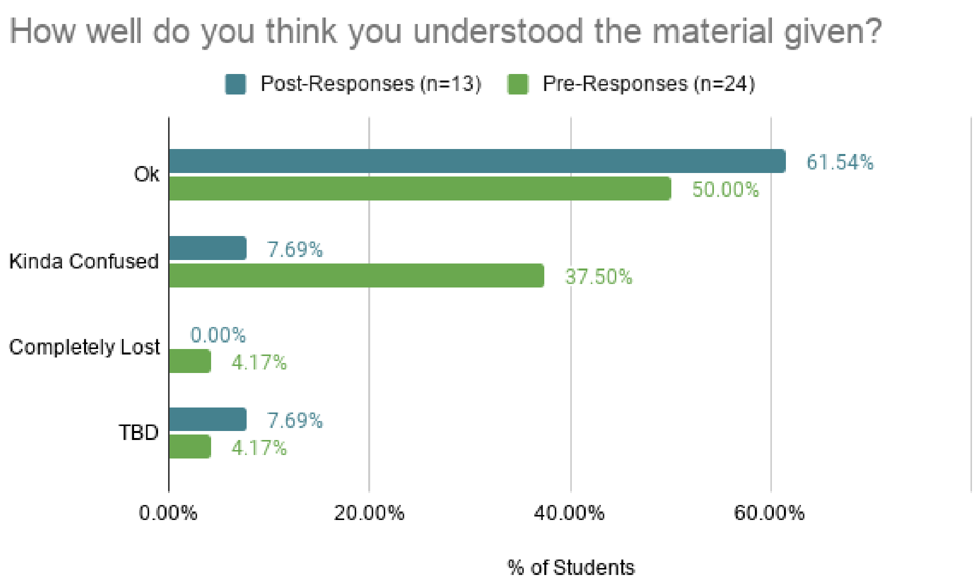

Figure 13: The following student's responses in relation to question 8 on the pre/post attitude survey.

Lesson Plan

For each of the given lesson plans, an evaluation form was given for the teacher to complete and send back upon completion as seen in appendix E1a. The form stayed consistent for each lesson plan and includes feedback about the lesson taught, the constructed questions only changed in regard to the final project, appendix E1b, and the online lab assignment pertaining to electromagnetism, appendix E1c. With a substantial number of students who have either chose not to do the given assignment and or not shown up to class, the teacher provided two grade sets for the assignments given. The first set of grades reflect all of the student whether or not they attempted the assignment, while the second set of grades only reflect the students who have attempted the assignments created.

Gravity

Below are the results from the given lesson plan detailed on the subject of gravity, the grades were relatively high and reflect the students' comprehension of the subject pertaining to the presentation implemented. Overall, the student's comprehension and engagement of the material was similar to that of previous years, however it was noted that the successfulness of the unit was deemed to be greater compared to previous years. All of the students responded positively to the paperclip and magnet exercise given. The only noted problem with the students refers to the remote students, who were given access to support videos posted to the student's google classroom page for further explanation and clarification of the subject matter given if they struggled with the assignment given. The students who were in class did not struggle with the assignment as they were able to ask the teacher questions while the remote students who did not refer to the support video nor contact the teacher struggled with the assignment. This can be further reflected with the teacher's responses in appendix E1b.

All Assignments

ASSIGNMENT	C-BLOCK GRADE AVERAGE	D-BLOCK GRADE AVERAGE
GUIDED NOTES	92%	73%
PAPERCLIP/MAGNET ACTIVITY	74%	78%

Completed Assignments Only

ASSIGNMENT	C-BLOCK GRADE AVERAGE	D-BLOCK GRADE AVERAGE
GUIDED NOTES	98%	100%
PAPERCLIP/MAGNET ACTIVITY	86%	79%

Electricity

Below are the results from the given lesson plan detailed on the subject of electricity and reflect the students' comprehension of the subject pertaining to the presentation implemented. Overall, the students' comprehension of the subject was similar to that of previous years, while the engagement and successfulness of the lesson plan was greater than average to that of previous years given. All of the students responded positively to the online balloon simulation. There were problems pertaining the remote students, as there were some who either did not complete one or both of the given assignments. The remote students also struggled more with the assignments compared to the students attending class in person, this is due to the students either not referring to the support videos the teacher posted for further clarification or not asking the teacher questions. This can be further reflected with the teacher's responses in appendix E1b.

All Assignments

ASSIGNMENT	C-BLOCK GRADE AVERAGE	D-BLOCK GRADE AVERAGE
GUIDED NOTES	80%	76%
PHET BALLOON ACTIVITY	89%	73%

Completed Assignments Only

ASSIGNMENT	C-BLOCK GRADE AVERAGE	D-BLOCK GRADE AVERAGE
GUIDED NOTES	91%	84%
PHET BALLOON ACTIVITY	94%	88%

Magnetism

Below are the results from the given lesson plan detailed on the subject of magnetism and reflect the students' comprehension of the subject pertaining to the presentation implemented. The teacher noted that the given grades were so low due to the lesson being given on a day where all students were to attend the class remotely, resulting in a substantial amount of student being absent for the given lesson. Overall, the students' comprehension and engagement in comparison to past years was the same, while the successfulness of the lesson was greater than average in comparison to previous years. For the students that did attend class, many of them reacted positively to the magnet/compass activity. For the remote students, many struggled as they did not refer back to the support videos the teacher made in hopes of further clarifying the given subject.

All Assignments

ASSIGNMENT	C-BLOCK GRADE AVERAGE	D-BLOCK GRADE AVERAGE
GUIDED NOTES	43%	65%
MAGNET/COMPASS ACTIVITY	64.5%	37.5%

Completed Assignments Only

ASSIGNMENT	C-BLOCK GRADE AVERAGE	D-BLOCK GRADE AVERAGE
GUIDED NOTES	64%	79%
MAGNET/COMPASS ACTIVITY	90%	75%

Electromagnetism

Below are the results from the given lesson plan detailed on the subject of electromagnetism, the grades were relatively high in reference to those completed in person and low in reference to those completed remotely. These grades reflect the students' comprehension of the subject pertaining to the past two PowerPoints, electricity and magnetism, presented. Overall, the students' comprehension and engagement were similar to that of previous years, while the successfulness of the lesson was greater than average to that of previous years. All students, regardless of whether in person or remote, reacted positively to the assignment given and were able to deduce that there is a relationship between electricity and magnetism.

All Assignments

ASSIGNMENT	C-BLOCK GRADE AVERAGE	D-BLOCK GRADE AVERAGE
ELECTROMAGNETISM LAB IN PERSON	82%	95%
ELECTROMAGNETISM LAB REMOTE	46%	49%

Completed Assignments Only

ASSIGNMENT	C-BLOCK GRADE AVERAGE	D-BLOCK GRADE AVERAGE
ELECTROMAGNETISM LAB IN PERSON	98%	95%
ELECTROMAGNETISM LAB REMOTE	49%	49%

Final Project

Below are the results from the given final project created, the grades were low in relation to the past in person assignments given, these results were intended to reflect the students' accumulative comprehension of all the lesson plans given as the final project incorporated all three topics: electricity, gravity, and magnetism. Overall, the students the students' comprehension of the topics was greater than average to that of previous years and the final project was deemed to be successful. All of the students reacted positively to the project, however there were struggles when the students were tasked with relating what they saw with the project to the maglev train real-world example. The teacher noted this struggle was more likely due to the students' comprehension level in relation to the sources given to aid in their final project as opposed to the project itself. The teacher also noted that even though most students found the online simulations useful and interesting, there were still students who did not attend class nor attempt to complete the assignments given.

All Assignments

ASSIGNMENT	C-BLOCK GRADE AVERAGE	D-BLOCK GRADE AVERAGE
FINAL PRESENTATION	61%	74%

Interview

After the intended two-week Unit finished, an interview commenced between the IQP team and the teacher. In the interview, the team requested feedback from the teacher and prepared the following questions:

1. How did everything go overall?
2. What were some key struggles you had encountered in person & virtually throughout the unit?
3. What were some key struggles students had in person & virtually throughout the unit?
4. Do you believe that some students demonstrated an interest in STEM that will carry on beyond this unit? If so, how many?
5. How did critique sessions go on the project?
6. How well did students collaborate together?
7. What were all the ways students present their final projects?
8. How well were students able to relate the unit in a way that affects society/themselves?
9. Do you have test scores from the previous year where PBL was not employed? If so, can you send us the averages?
10. Any discernible difference amongst demographics (ages, gender, ESL, primary English speaker, etc.)
11. Is there anything that should have been done differently?

The teacher concluded that the given unit was successful with many students reacting positively to the activities and online simulations. When asked about the previous approaches to the given standards of, 7.MS-PS2-3 and 7.MS-PS2-5, the teacher utilized PBL as well and would often use a set of magnetic train cars to demonstrate different forces. As the teacher favors hands-on learning, the implementation of PBL was not difficult. The students were responsive to the given assignments when in class, but there were struggles as students would not complete or attempt the given online work or attend the zoom meetings in the current hybridized setting the given school has chosen to utilize. Due to time constraints and the inclement weather conditions, the given lessons were pushed back further than anticipated, resulting in some lessons being taught on days where all the students were online instead of in person. Following this, there was also a problem with the final project as originally there were intended to be two sets of different race cars the students would utilize to observe how different physical forces interact, one set powered by an electromagnet and one powered by a magnet. The car intended to show how different forces can interact in relation to an electromagnet was removed as the teacher could not attach the electromagnet to the car due to the car's design. The time constraint also prevented the teacher from allowing the students to have free will in how they would choose to present the final project as well; the teacher instead gave a template that the students were to complete.

The students also struggled with the vocabulary used on the majority of assignments and given material, as many of the students could not understand the verbiage used on the assignments but were able to once the teacher clarified the question further, this comment generally refers to the analysis questions and the subject of electromagnetism. Given this, the teacher created demonstration videos for the assignments as about 50% of the students struggled to understand the instructions detailed in the assignments, this was not limited to a certain lesson and was applied to the whole unit. With this the teacher also saw that many of the students struggled with comprehending the connection between what was being presented in class to real-world examples given, i.e., the bullet train. The teacher believes this was not due to the lessons or the project given but instead due to the comprehension level required to understand the sources given in comparison to the students' literary comprehension level. The teacher saw that many students also struggled when the student themselves had to be "self-starting" as with the lack of direction, many students chose not to complete that given question in the final project.

The teacher stated in the interview that, “Many students collaborated with each other, whether it was intended or not. The students collaborated well together, and the work was shared equally...”. Many of the students asked each other questions even when the given work was asked to be completed individually. When asked whether or not the teacher believed the unit was taught efficiently and whether or not they would change something, the teacher stated that they believed the given lesson plans and unit were “perfect” and they intended to share the given material with the whole department because of the adaptability of the material, followed by the positive reception of the students.

Discussion

To obtain a relative understanding of the students’ general comprehension of the material, a pre and post knowledge assessment were utilized to evaluate the students’ ability to understand and learn the material. The questions asked, emphasized the key points of the two standards and the major factors of the project. These questions focus on how different forces interact with each other even when they cannot be seen, followed by how well students are able to collect, organize, and analyze data. Due to time constraints, not all of the students completed the post assessments. For the pre/post assessment for knowledge, only ten students out of the original 24 responded.

In continuation to this, an attitude assessment was given to analyze how students felt about the STEM field, and associated subjects. The attitude assessment was utilized to emphasize the students’ impressions of the STEM field, with the majority of the students being confident in one of the given STEM fields, it was anticipated that the lessons given were to be received positively by the students. Due to time constraints, not all of the students completed the post assessments. For the pre/post assessment for attitude, only thirteen students out of the original 24 responded.

The team believes the project was executed well under the unique circumstances given. These factors include inclement weather conditions, lack of student attendance, time constraints, and missing or incomplete work. The inclement weather caused the lessons to be presented days apart from one another and pushed certain lessons that were intended to be presented in person to be then presented on a zoom meeting remotely. The lack of student attendance in tandem with the missing and or incomplete work was detrimental to the results. This is because it forces the creation of two different sets of data that are both significant, one that reflects the comprehension of all the students, and the other that reflects the comprehension of only the students that completed the assignment given. In conjunction to this, the time constraint denied the students the ability to freely be able to decide how they would want to present their data for the final project.

The final project initially was intended to demonstrate how all three forces interact with one another in relation to designing a racecar, however the final project implemented and observed by the students only focused on magnetism. This was due to the race that was utilized was done on a horizontal plane instead of a ramp, therefore the relationship demonstrated would be one between magnetism, electricity, and inertia instead of gravity. This is problematic as the standard given does not include inertia to be discussed and is detrimental, as the project did not demonstrate how gravity can interact with both electricity and magnetism. Due to the problems with properly securing the electromagnet to the car's body, the car dedicated to electromagnetism was removed. This is also problematic as this car was deemed to be important to the unit given its relation to students' comprehension of all three lessons given in the unit. Also, because it limits the amount of data available for the students to collect. Due to the limited time frame allowed, the correlating quizzes formulated by the team for each of the following subject topics, gravity, electricity, and magnetism, were not implemented. Instead, the teacher chose to analyze the students' comprehension of the topics by reviewing the given handouts; guided notes for each of the topics, paperclip/magnet activity, PHET balloon, magnet/compass handout, and the electromagnetism.

The pre-assessments were given prior to presenting the lesson plans, with the post assessments intended to be completed immediately after all the lessons were fully presented. Due to time constraints the post assessments were given three weeks later, and not all the students completed the post assessments. This is not ideal as the information taught in the given lessons was no longer immediately present in the students' minds. The data set obtained also is not as accurate as it could be, as there was a substantially lower number of answers obtained for the post assessment compared to the pre assessment.

Conclusion and Recommendations

Effectiveness in Teaching, Final thoughts from Mrs. DeMaria, and Survey Results

The primary goal of this project was to ensure that the standards *MS-PS2-3* and *MS-PS2-5* were met through employing a PBL unit in the given teacher's classroom. During an interview held with the teacher after the project was implemented, it was mentioned how they enjoyed the level of engagement the unit provided for her classroom. It was noted that student engagement was substantially higher than usual, with students eager to solve problems throughout the unit. The teacher highlighted that the hands-on activities in conjunction with lectures, and handouts were executed efficiently and ultimately led to higher student interest. They noted that student interest was high enough that some students are even choosing to conduct unrelated projects based on the topics taught in the PBL unit. The teacher also noted that there were issues with teaching the unit however, as they felt this PBL unit was an improvement from previous years. The ease of employing PBL may be due in part to the teacher having previous experience with implementing PBL as well as the students having prior exposure to PBL

With the results from the Post-Assessments showing improvement, as there was an average of a 15% increase in correct responses from the Pre-Assessment. This increase, however, is heavily impacted by the lack of students completing the Post-Assessment, as 24 students originally completed the Pre-Knowledge Assessment, but only 10 students completed the Post- Knowledge Assessment. The students also reacted positively to the lessons given which positively impacted their attitudes towards STEM, as can be seen with the Post-Attitude Assessment. This positive reaction however is also impacted by the lack of students completing the Post-Attitude Assessment, as 24 students originally completed the Pre-Knowledge Assessment, but only 13 students completed the Post-Attitude Assessment. The team ultimately concluded that the state standards were proficiently met through a PBL unit as well as PBL proving to be an effective active learning method to increase student interest in STEM as well as the proficiency in which these STEM units were taught, as seen from the responses obtained by the Post-Assessments.

Ease of Deployment

A goal that was noted during the design process of the project was the ease of implementation of the project. A plausible way to ensure this was for a majority of in-class activities to be low cost, and for assignments and handouts to be easily employed virtually. Many activities such as the balloon experiment, the ball drop for the gravity unit, and the magnetic field activity all require items which are commonly found in a school, if not the given items are relatively inexpensive and cost less than $50. It was also ensured that the final project would be financially inexpensive with the final project requiring; popsicle sticks, toy wheels, skewers, washer weights, magnets, and electromagnetics. With the majority of these items being found in either a craft store or already present in a school. However, the electromagnet is the only item which is not easily found in schools. It was noted though, that an electromagnet can be created with relatively inexpensive materials that can all be found at a hardware store; copper wire, battery, and an iron nail. As a result, everything needed for this PBL unit in total should sit well below $100. To further aid those who wish to recreate this unit, all the relative course documents can be found in the appendix.

Implementation

Once all the final versions of the respective lesson plans and supporting material were completed a meeting was held with the teacher to discuss the logistics of implementation. Due to COVID-

19, the given school was operating on a hybrid basis. Students would virtually attend class some days and physically attend class other days. The rotation schedule inherently limited the number of days the students were physically present in school. Consequently, we worked with the teacher to ensure that all activities are completed in person while any material which can be completed online are assigned on virtual days. As a result, a final schedule depicted in figures 5 & 5 was formulated for when the teacher began to implement the unit into the classroom. In the region in which this study was completed, inclement weather conditions were a common occurrence which were not accounted for when formulating the schedule. As such, certain activities which may have been intended to be employed in person were then employed online, such as lectures which helped relieve some of the time restrictions that unexpected weather created. This was done with relative ease however, as the majority of assignments were formulated with the chance of having to be employed remotely, was kept in mind.

Challenges

Throughout the deployment of the unit, a few challenges persisted. One major issue, which inhibited the team's ability to gauge the effectiveness of the unit, was the low completion rate amongst the activities assigned remotely. Students chose not to virtually attend class and/or failed to complete assignments for these remote days. There were no specific reasons for the lack of attendance that could be determined by both the teacher or the team. This occurrence highlighted how the students who completed the virtual assignments and attended class incurred a better performance and overall attitude to the unit. It is also important to note that there were no issues with the students who did attend class in person. Another challenge that arose, is in relation to the students' ability to follow written instructions. Followed by answer questions that ask for the students to relate their observations to real world applications. Roughly half of the students did not understand the question before them which resulted in a low completion rate on those parts of the assignments. The teacher mitigated this problem by answering questions in class and creating online videos that clarified those parts of the assignment for students. However, a low completion rate was still seen.

Due to the nature of the school's classroom schedule where students rotated between in person and remote learning days, an inherent time constraint was stated from the beginning of the project. The team worked with the teacher to formulate a final schedule that allowed enough in person time for activities and more difficult assignments. While also allocating the remoter days to less intensive material. However, due to the inclement weather, the schedule was forced to be altered. Although all material was able to be covered due to the flexibility of swapping in person assignments with remote assignments, there were now less days remaining in the academic calendar. As a result, the quizzes on magnetism, electricity, and gravity were not deployed. Instead, the teacher graded the handouts for student grades and the final aspect of the project was altered. Students were also originally asked to present their final project in any manner that they desired; however, the time constraint forced the teacher to have students present their project using a generic template.

Two other challenges were also encountered during the final project. The first being that the electromagnet race car had to be removed from the project due to issues with having the electromagnet functioning on the car, as well as securely attaching the magnet to the popsicle stick. The second challenge was that gravitational fields were not employed in the project. The team had the weighted cars race on a flat surface as opposed to an inclined surface. This demonstrated inertia forces as opposed to gravitational forces. As a result, students were only able to observe magnetic fields as opposed to being able to observe gravitational, electrical, and magnetic fields.

Final Thoughts & Recommendations

The team recommends that the next time this project is employed, a wider base popsicle stick is used so that an electromagnet can be seated properly on the car. We also recommend the race with weights on each car be completed on an incline so students can correctly identify gravitational forces interacting. It is also suggested that clarifying videos should be created for assignments that require students to follow explicit written directions as well as for assignments that ask questions that require sustained inquiry. As the teacher reported that video resources aided in the unit implementation. The time constraints which arose due to inclement weather conditions can possibly be avoided by shortening some of the lessons on magnetism, electricity, and gravity. Some specific suggestions can be limiting the number of questions asked on the worksheets or only employing guided notes. The final recommendation the team suggests, is to provide more incentive for students to attend virtual lectures, and complete virtual assignments. Possible incentives can be a pizza party which follows COVID-19 safety measures, promises of a movie day for students, or extra recess time.

Overall, the team felt that the project was successful given the challenges. The teacher's interview paired with the student's average scores on assignments showed that student comprehension in STEM increased for those students who did participate. Student interest in STEM increased in relation to all students, and students were able to retain previous knowledge about each field and apply it to their project. Having students interested in the topics they are being taught is a difficult task to accomplish, but the hands-on activities paired with a final project demonstrated a successful way to sustain student interest in STEM as well as make students enthusiastic to learn about STEM and solve STEM related problems as seen during implementation.

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Appendix A

Section	Author
Abstract	Makayla Carmichael
Introduction	Hossam Elaskalani
Methodology	Hossam Elaskalani
Results & Discussion	Makayla Charmichael
Conclusion	Makayla Carmichael
Appendix	Makayla Carmichael & Hossam Elaskalani
Citations	Hossam Elaskalani

Appendix B

B1. Gravity Lesson Plan

Lesson Plan Title: Gravity

Teacher's Name:

Subject/Course: 7th Grade Physics

Unit: Gravity Unit Plan

Grade Level: 7th Grade

Overview of and Motivation for Lesson:

To prove the existence of gravitational fields as well as provide explanation on the workings behind gravitational fields

Stage 1-Desired Results

Standard(s):
- MS-PS2-5. Use scientific evidence to argue that fields exist between objects with mass, between magnetic objects, and between electrically charged objects that exert force on each other even though the objects are not in contact. Clarification Statement: • Emphasis is on evidence that demonstrates the existence of fields, limited to gravitational, electric, and magnetic fields. State Assessment Boundary: • Calculations of force are not expected in state assessment.

Aim/Essential Question:
- Why does an object of a larger mass create a field that can impose force upon smaller objects?
- Why does distance have an effect on gravitational force?

Understanding(s):
Students will understand that . . .
- Objects with mass (such as planets) have a field existing between them that accounts for our day to day phenomenon
- Gravity is considered to be a force imposed by an object of a larger mass onto a smaller mass object in respect to distance between the two objects
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but that force depends on the mass & distance between the two objects.
- The paper clips can “defy” gravity due to magnetic attraction however because of gravity’s force, the paper clips must be very close to the magnet for this to occur.
    - The magnetic force can overcome gravity with a small enough distance, however gravity overcomes magnetism once the paperclip is far enough away

Content Objectives:
Students will be able to . . .
- Make a claim about the phenomenon of gravity and support it.
    - Claim must include that gravitational interactions are attractive & dependent upon mass & distance between the two objects.
    - Claim must also include that gravitational attraction can be overcome by magnetic attraction under certain circumstances
- Support this claim on the final question in the supplemental worksheet.

Language Objectives:
ELD Level Choose an item. *Students will be able to . . . in English*
Click here to enter text.
ELD Level Choose an item. *Students will be able to . . . in English*
- Click here to enter text.

Key Vocabulary
- Gravitational Force - The force exerted upon an object onto another object of a larger mass.
- Mass - the amount of matter in an object, mass stays the same weight changes with gravity.

Stage 2-Assessment Evidence

Performance Task or Key Evidence

- Students will go through the paper clip & magnet gravity experiment writing down any observations they see to the paperclips in various scenarios

- Students will then be asked to fill out a worksheet & guided notes relating back to the bigger picture of gravity's relationship with masses and objects.

- Students will then have to successfully complete an online quiz to complete at home discussing: Relationship of gravity between the size of two objects & the relationship of gravity between the distance between those two objects.

Key Criteria to measure Performance Task or Key Evidence

- The student's scoring full credit on quiz sections discussing gravity's relationship with mass & distance will demonstrate their basic understanding.

- If a student is able to successfully answer #5 on the worksheet associated.

Stage 3- Learning Plan

Learning Activities:

Do Now/Bell Ringer/Opener: Tell the students to ignore the paperclip & magnet set up on their tables for now and once everyone is ready, drop a ball onto the ground and spend 3 minutes asking students their thoughts on why the ball dropped guiding their answers towards gravity.

Learning Activity 1: **Paperclip & Magnet Activity (**20 Minutes**)**

Note that students will conduct this experiment in small groups however briefly explain the instructions and do this experiment step by step as a whole class.

Introduce the paperclip & magnet demonstrations

- Follow steps outlined in the Paperclip & Magnet Handout associated with this lesson
- At the end of the demonstration make it clear via demonstration that the paperclips will "defy" gravity by coming into contact with the magnetic field (which can surpass gravity's force with a short enough distance) then the distance from the magnet will slowly increase to demonstrate how gravity's effect will eventually overcome the magnetic force between the two objects.

Learning Activity 2: **Powerpoint Presentation (**15 Minutes**)**

- Have students pull out their guided notes and begin the Gravity Powerpoint
  - On slide 2 allow for a brief discussion (~2 minutes) and guide answers to lead to gravity being a force.
- When presenting the visual of the gravitational equation, summarize the relationship between masses and distances on the board
  - Make sure students have this written down as it will be vital in their project

- For slide 6, encourage students to think back to what they saw during the activity done.
- If time allows, have students watch the linked video in slide 7, if not assign the video to be watched for homework.

Application

On the worksheet, students will be asked to provide an example of gravity in the real world, and explain how gravity is in effect using the relationship of mass and distance to gravitational force. Students will also be asked to determine how gravity is applied in their final project activity as well as learn how to use gravity for their advantage.

Summary/Closing

- After the video, make sure students are clear on the assigned quiz and worksheet that must be done and class can be dismissed.

Multiple Intelligences Addressed:

☐ Linguistic	■ Logical-Mathematical	☐ Musical	☐Bodily-kinesthetic
☐ Spatial	☐ Interpersonal	☐Intrapersonal	☐Naturalistic

Student Grouping

■ Whole Class	■ Small Group	☐ Pairs	☐ Individual

Instructional Delivery Methods

■ Teacher Modeling/Demonstration	■ Lecture	■ Discussion
☐ Cooperative Learning	☐ Centers	☐ Problem Solving
☐ Independent Projects		

Accommodations	**Modifications**

Homework/Extension Activities:

There will be guided notes, worksheet, & quiz due 48 hours after the cohort has met.

Materials and Equipment Needed:

- Paperclips
- String
- Ruler
- Some sort of rod
- A few textbooks
- Magnets of varying sizes and strengths

Adapted from Grant Wiggins and Jay McTighe-*Understanding by Design*

B2. Magnetism Lesson Plan

Subject/Course: Physics/ Physical Science
Unit: Physical Forces Magnetism
Grade Level: 7th Grade

Overview of and Motivation for Lesson: To prove the existence of magnetic fields and provide an explanation behind the workings of these fields.

Stage 1 — Desired Results

Standards:
- 7.MS-PS2-5. Use scientific evidence to argue that fields exist between objects with mass, between magnetic objects, and between electrically charged objects that exert force on each other even though the objects are not in contact. Clarification Statement: • Emphasis is on evidence that demonstrates the existence of fields, limited to gravitational, electric, and magnetic fields. State Assessment Boundary: • Calculations of force are not expected in state assessment.

Aim/Essential Question:
- How do we observe and analyze magnetic fields
- How do like and unlike poles react with one another
- How do different fields interact and affect each other

Understanding(s)

Students will understand...
- the effects different types of fields and forces have with one another
- attractive and repulsive forces from the resulting different poles
- how to recognize the different forces that could be interacting with one another

Content Objectives:

Students will be able to...
- see that different fields exist even if they can't be seen physically
- see that fields can interact with each other without physically touching
- recognize the resulting force from like and unlike poles interacting

Vocabulary
- Attraction - the force that acts between oppositely charged bodies, tending to draw them together
- Repulsion - the force that acts between likely charged bodies, tending to draw them away
- Force - an interaction that, when not challenged, will change the motion of an object
- Magnitude - size or extent of an amount
- Magnetic Poles - the two points of a magnet furthest from the center
- Magnetic fields - an area around a magnetic material or a moving electric charge with which magnetic force acts

Stage 2 — Assessment Evidence:

Performance Task or Key Evidence

- Students will be asked how you can move a magnet with another magnet without touching it
- Students will be tasked to explain how an electromagnet can work

Key Criteria to measure Performance Task or Key Evidence

- Students will be able to give a reasonable explanation as to how an electromagnet works
- Students will be able to score above a 70 on the following assessment

Stage 3 — Learning Plan

- Day 1
- Learning Activities
    - Guided Questioning [Opener/Do Now] (3-5 Minutes)
        - the instructor will ask questions to inquire about the student's inherent understanding of the topic being taught and their knowledge of interacting magnetic forces.
- "If rollercoasters are powered by gravity essentially speaking, give or take a few things here or there, then how would you bring the cars back up the track to reset the ride?"
- "What are magnets?"
- We learned about attraction and repulsion when talking about electricity, how do you think the same concept of attraction and repulsion can apply when it comes to magnetism?"
- Challenge/Worksheet (10-15 Minutes)
        - The instructor will give each student two magnets and then challenge the student to try and see if they can push a magnet off a table, using only the magnets and the magnets can't be touching each other.
        - Students should attempt to push the magnet off using attractive & repulsive forces.
- There will be a worksheet with instructions that the students should complete
- Some if not most of the students will be able to complete the task given, once an adequate number of students are able to complete the task given, ask the students how they were able to push the magnet off of the table
            - ie...you could ask how they were able to push the magnet off of the table
- This activity will then lead to the corresponding notes that will then be given to help further explain the following ideas
    - Notes (15-20 Minutes)
        - The corresponding slide show will then be presented to help clarify and further explain the topic of magnetism.
- The students should be instructed to take notes and the instructor should engage the students to help further explore the topic
        - There will be a question given at the end of the slide show that should engage the students as it'll require them to critically and logically think about the material that has been given to them
- Ideally the solution to the question that was given would be executed in front of the students and or have the students try and physically figure out the solution themselves, however due to covid and limitations the instructor may have to complete the solution given and show to the class in the form of a demonstration and or if that's not possible a video has been given as well to show the solution

Multiple Intelligences Addressed

- Logical-Mathematical

Student Grouping
- Individual
- Small Groups

Homework/Extension Activities
- - Online Class, video to help explain different types of forces and a corresponding worksheet
- - Online Class, digital simulator to show magnetic fields and then a quick quiz to check understanding

Materials and Equipment Needed:
- Magnets
- Cardboard
- Battery
- Copper Wire
- Legos
- Washers/Nuts

B3. Electrical Fields Lesson Plan

Subject/Course: Physics/Physical Science
Unit: Electricity and Electrical Forces
Grade Level: 7th Grade

Overview of and Motivation for Lesson: To prove the existence of electrical fields and to describe the workings of these fields.

Stage 1 — Desired Results

Standards:
- 7.MS-PS2-3. Analyze data to describe the effect of distance and magnitude of electric charge on the strength of electric forces. Clarification Statement: • Includes both attractive and repulsive forces. State Assessment Boundaries: • State assessment will be limited to proportional reasoning. • Calculations using Coulomb's law or interactions of sub-atomic particles are not expected in state assessment.

Aim/Essential Question:
- How do we observe and analyze electric fields/charges
- What's the result from like and unlike charges interacting with one another
- How does distance between charges effect the magnitude of the resulting electrical force

Understanding(s):

Students will understand...
- the effects of like and unlike charges interacting and the resulting electric forces
- the effect of distance between interacting charges and the resulting effects it has on the magnitude of electrical force

Content Objectives

Students will be able to...

- see that electric fields exist even if they can't be seen
- recognize the effect distance has on the magnitude of electrical force
- why there are positive and negative charges,
- see the resulting forces from like and unlike charges interacting
- how to organize their data into a table
- how to plot their data into a line graph to graphically show their data results

Language Objectives

—-

Vocabulary:

- Attraction - the force that acts between oppositely charged bodies, tending to draw them together
- Repulsion - the force that acts between likely charged bodies, tending to draw them away
- Positive - charge from protons
- Negative - charge from electrons
- Magnitude - size or extent of an amount
- Charge - the basic property of matter that carries some basic particles that determine how an object will react in electric or magnetic fields
- Electric fields - an area around a charged particle or object with which a force would be pushed onto another charged particle or object

Stage 2 — Assessment Evidence

Performance Task or Key Evidence:

- Students will be tasked to create a graph based to show the effects distance has on electrical force.
- Students will be asked how a balloon can push a stream of water away by the use of electric charge.
- Students will be tasked to complete the following online google forms quiz to reflect on how well they comprehended the following topics.

Key Criteria to measure Performance Task or Key Evidence:

- Students will be able to correctly organize data into a table and create a correlating line graph.
- Students will be able to give a reasonable explanation as to how electric charge can push a stream of water away from a balloon.
- Students will be able to score above a 70 on the following assessment.

Stage 3 — Learning Plan

- Day 1:

- Learning Activities:
  - Guided Questioning [Opener/Do Now] (3-5 Minutes)
    - The instructor will ask questions to inquire the students inherent understanding of unseen forces and electric fields and charges.
- Questions will be:
  - "People say opposites attract do you think that's true?"
  - "You know how you can "shock" people in the winter? Well do you know how that happens?"
  - "If opposites attract in everyday life, how does this work when it comes to "shocking" people?"
  - Challenge/Worksheet (10-15 Minutes)
    - Instructors will challenge the students to try and make a balloon stick to their chest by having students rub the balloon against their chest then releasing the balloon.
- There will be a handout that the students should complete beforehand.
- Some if not most students will be able to perform this task, once one does so, ask the student how this happens.
  - ie...you could ask the student how the balloon stuck to their chest
    - This activity will lead into the corresponding notes on the second section of the handout that will then be given to help further explain the following idea.
  - Notes (15-20Minutes)
    - The corresponding slide show will be given to help clarify and further explain the topic of electricity.
- The students should be instructed to take notes and the instructor should engage the students to help further explore the topic.
    - There will be a question given at the end of the slide show that should engage the students as it requires them to critically and logically think about the material that has been given to them
- Ideally the solution the question that was given would be executed in front of the students and or have the student's try to physically figure it out themselves, however due to COVID limitations, the instructor may have to complete the solution given and show to the class in the form of a demonstration and or if that's not possible a video has been given as well to show the solution

Multiple Intelligences Addressed
- Logical-Mathematical

Student Grouping
- Small Group
- Individual

Homework/Extension Activities
- \- Online Class, digital simulator & worksheet
- \- Online Class, at home lab

- Students will follow a lab outline to show how the magnitude of an electric field decreases with an increase of distance between to charges, this data will then be logged into a data table and then plotted on a line graph to show the negative trend line

Materials and Equipment Needed:

- A lab outline (already made)
- Scotch tape

B4. Project Lesson Plan

Lesson Plan Title: Final Project

Teacher's Name: **Subject/Course:** Physics

Unit: Gravity, Electricity, and Magnetism **Grade Level:** 7th Grade

Overview of and Motivation for Lesson:

To understand how electrical, magnetic, and gravitational fields work and how we can use them for our advantage

<table>
<tr><th colspan="2">Stage 1-Desired Results</th></tr>
<tr><td colspan="2">Standard(s):
MS-PS2-5. Use scientific evidence to argue that fields exist between objects with mass, between magnetic objects, and between electrically charged objects that exert force on each other even though the objects are not in contact. Clarification Statement: • Emphasis is on evidence that demonstrates the existence of fields, limited to gravitational, electric, and magnetic fields. State Assessment Boundary: • Calculations of force are not expected in state assessment.</td></tr>
<tr><td colspan="2">Aim/Essential Question:
How do all the fields work together to give the fastest car, and the slowest car?
Why can fields exert force upon one another without contact?
How can you make the slowest car, the fastest car?
Why are fields applicable in our daily lives?</td></tr>
<tr><td colspan="2">Understanding(s):
Students will understand that . . .
Gravity is one of the reasons why heavier objects are slower when trying to move.
Magnetic fields can be used to propel something forwards/backwards.
Electric fields can also be used to propel something forward and backwards.
There is a range in which these fields have an effect.
Greater the distance between the two objects = the lesser of the effect of the field being used.
These fields are vital for certain innovations in our world such as the bullet train.</td></tr>
<tr><td>Content Objectives:</td><td>Language Objectives:</td></tr>
</table>

Students will be able to . . .	ELD Level Choose an item. *Students will be able to . . . in English*
• Explain how fields can have an effect on an object without an object touching another. • How to take advantage of these fields to produce something beneficial for themselves & society. • Explain on a qualitative level how the fields work together to produce the outcome seen in the activity..	Click here to enter text. ELD Level Choose an item. *Students will be able to . . . in English* • Click here to enter text.

Key Vocabulary

- Gravitational Force - The force exerted upon an object onto another object of a larger mass
- Mass - the amount of matter an object contains.
- Attraction - the force that acts between oppositely charged/poled bodies, tending to draw them together dependent upon distance.
- Repulsion - the force that acts between like charged bodies/poles, tending to draw them away dependent upon distance.
- Force - an interaction that will change the motion of an object.
- Magnitude = size or extent of an amount.
- Magnetic Poles - the two points of a magnet furthest from the center.
- Magnetic fields - an area around a magnetic material or a moving electric charge in which magnetic force acts.
- Positive - charge from protons
- Negative - charge from electrons
- Charge - the basic property of matter that carries some basic particles that determine how an object will react in electric or magnetic fields.
- Electric fields - an area around a charged particle or object with which a force would be pushed onto.

Stage 2-Assessment Evidence

Performance Task or Key Evidence

- Students will be briefed on their role as an engineer at an automotive manufacturing company, as well as their task.
- Students will run through the instructions given for the project handout.
  - Students must be taking notes on each race results as well as any further observations about each car.
- Students must complete the section titled: “Bringing it all together” and present it in an appropriate format
  - Provide students with a basic rundown on the section by summarizing each bullet point and answer any questions.

Key Criteria to measure Performance Task or Key Evidence

- Conducting the in class experiment and writing down observations about the results of each car raced.
- Present a project that discusses how the fields work together to provide the quickest car.
- Presentation must include the following
    - What car seemed to travel the most distance over the quickest time in comparison to each race?
        - What about in comparison to all races?
    - What type of field plays the biggest role in making a car move quickest and what field made the car move the slowest?
        - Must explain why they think this, and if there is there any way they can make the slowest moving car quicker than the fastest moving car with an explanation.
    - They must investigate the “bullet” train, understand how it works and see if they can hypothesize a way to apply this for the race cars.
    - Relate ⅔ fields discussed to an example in the real world.
- Students have to attend a review & critique session with the instructor.
- Students will have to present their project in any appropriate manner desired.

Stage 3- Learning Plan

Learning Activities:

Do Now/Bell Ringer/Opener:

Start off class by telling students today they’re going to take all that they’ve learned & put it into good use. (1 minutes)

Note: Project handout and the cars should already be set up for students to run their experiments

Learning Activity 1: Introducing the Activity

- Have students look at the sheet and go over the steps of each race with the students.
- Make sure students understand how to do each race by demonstrating a “dummy” race in front of them using a regular magnet and electromagnet car.
- Clarify that students understand how the magnet makes both the magnetic cars and electromagnet cars move.

Learning Activity 2: Going through the Activity

- Have students have a notebook and pen ready to take note of the results of each race.
- Have students do the first race and walk around making sure that they are doing the race correctly

  - ○ Ask guided questions so they fully understand what's going on between the race cars and fields.
- Once the first race is complete, ask students briefly (2 minutes) what they noticed about each car's performance.
  - Guide their responses so they are using terms like "magnetic field," attracting/repelling," "gravity affecting the heavier car," etc.
- Have students run through the second race and walk around making sure that they are doing the race correctly
  - Ask guided questions to ensure comprehension of the fields in play.
- During the duration of the activity, make sure that students are taking sufficient notes on the results of each race.

Application

Students will apply what they've seen in the activity to the section "Bringing it all together."

- Go through and summarize the section and each basic requirement
- Make it clear to the students that they will be using their notes to do a considerable portion of this project
  - Use this time to let students ask about any clarifying questions in regards to how the fields work in each of the two races.

Summary/Closing

- Ask the students as group to explain the main driving force for why the heavier car in race 1 was the slowest
  - Answer should relate to gravity
- Ask the students why the strongest electromagnet car was the quickest car in race 2
  - Answer should relate to electrical fields
- Ask the students why we had to use the positive and negative poles of the magnets to make the race happen.

Multiple Intelligences Addressed:

☐ Linguistic	■ Logical-Mathematical	☐ Musical	☐ Bodily-kinesthetic
☐ Spatial	☐ Interpersonal	☐ Intrapersonal	☐ Naturalistic

Student Grouping

■ Whole Class	■ Small Group	☐ Pairs	☐ Individual

Instructional Delivery Methods

■ Teacher Modeling/Demonstration	☐ Lecture	■ Discussion
☐ Cooperative Learning	☐ Centers	☐ Problem Solving
■ Independent Projects		

Accommodations	**Modifications**
Click here to enter text.	Click here to enter text.

Homework/Extension Activities:

Holding “office hours” could be useful for students and is strongly suggested for this project.
Materials and Equipment Needed: ● Legos ● Magnets (make sure the back of your car has the negative end attached to it) ● Cards ● Electromagnets ● Flat long table to run the race on

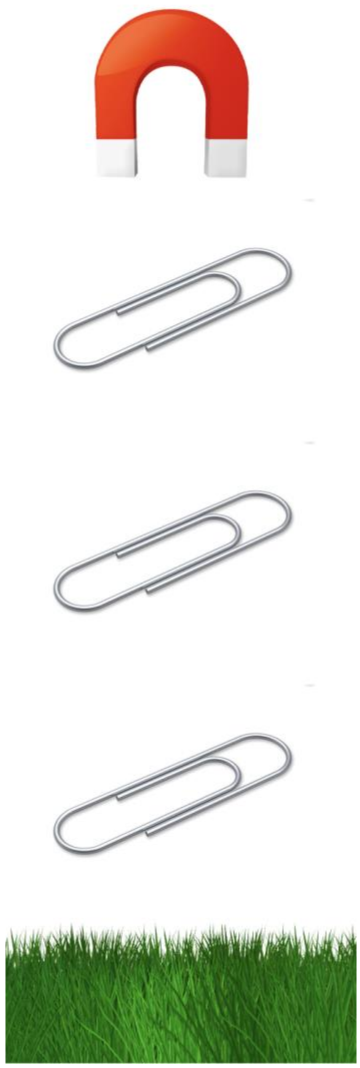
Adapted from Grant Wiggins and Jay McTighe-*Understanding by Design*

Appendix C - Check-in Quizzes

C1. Gravity Check-in Quiz

1.) Define gravity (gravitational force) in your words?

2.) If the magnets were far enough away to ignore magnetic forces, would the paperclips be attracted towards the Earth or the magnets? Why?



3.) Why can we jump higher on the Moon than on the Earth? (Hint: The moon's mass is less than the Earth)

4.) What if we had two scenarios? Scenario A: You are 10,000 km (6,200 miles) off the ground (This is the edge of the atmosphere!) Scenario B: You are flying on an airplane 9 km (5.6 miles) off the ground. In which case would gravity be stronger, and in which case would gravity be weaker? How could you manipulate your position so that when you experience the weaker force of gravity it now becomes the greater force of gravity?

C2. Magnetism Check-in Quiz

Magnetism

* Required

Where are the poles on a magnet? *

When do magnets repel each other? attract each other? *

Can all metals become magnetic? *

(A) Yes
(B) No

Magnetic fields are....? *

(A) created by charges interacting with each other
(B) created by electrons moving
(C) created by electric charges moving
(D) created from the area around a charge

What is Magnetism? (select all that apply)

(A) a force
(B) a charge
(C) something we can't see
(D) something caused by electricity

C3. Electricity Quiz

Electricity

* Required

Electrons are particles that have a.... *

(A) Negative charge
(B) Positive charge

What is an electric field? What type of electric field is around an electron? *

Protons are particles that have a... *

(A) Positive Charge
(B) Negative Charge

Repulsion is caused by.... *

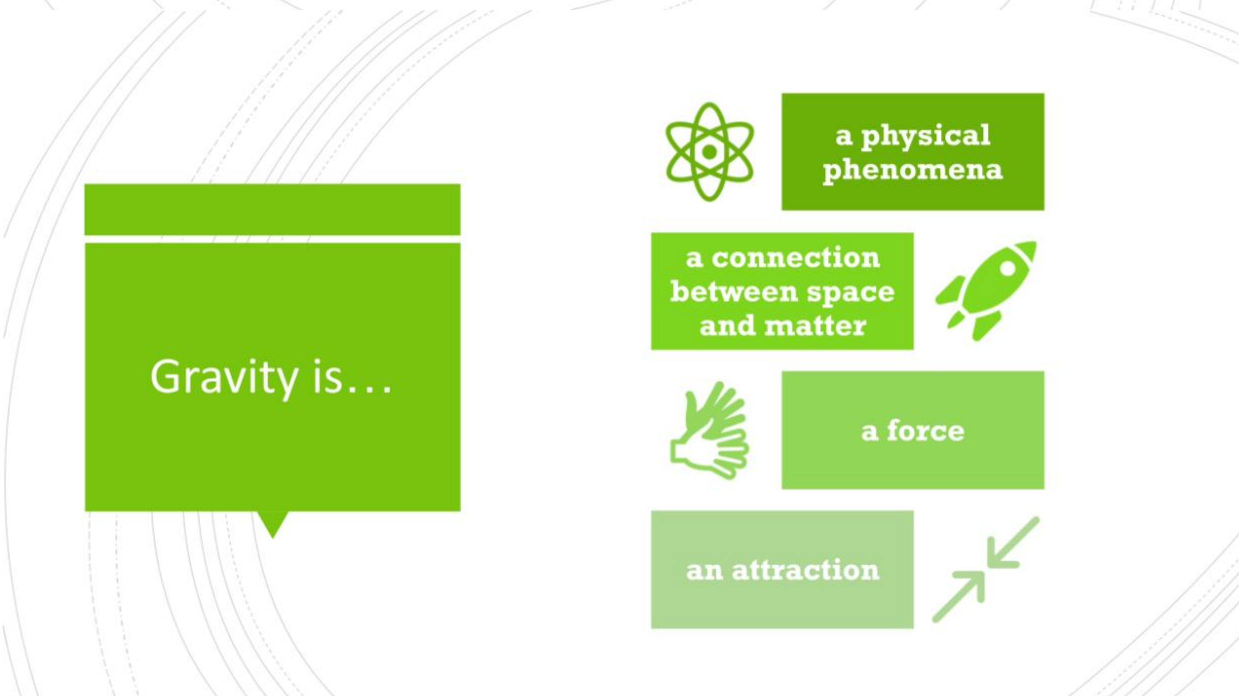
(A) like charges interacting
(B) unlike charges interacting

Electricity is...?(select all that apply) *

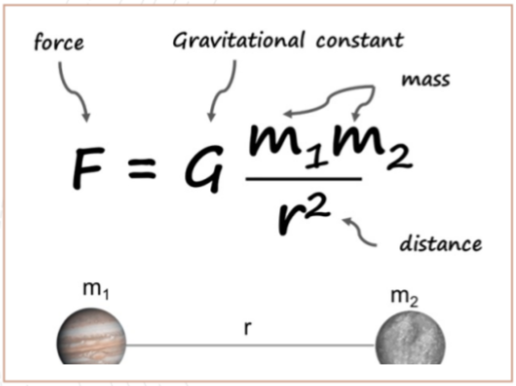
(A) something we can’t see
(B) a type of energy
(C) Magnetic
(D) something created by magnetic poles

Appendix D - In class Powerpoint, Class Worksheets, Handouts, and Quizzes (Gravity, Electricity, and Magnetism, and Project Respectively)

D1a. Gravity Powerpoint



Gravity is…



- **A force that relates the interaction between objects with mass**
  - The greater the mass the greater the force of gravity will be, inversely the smaller the mass the weaker the force of gravity will be
  - The smaller the distance the greater the force of gravity will be, inversely the greater the distance the weaker the force of gravity will be

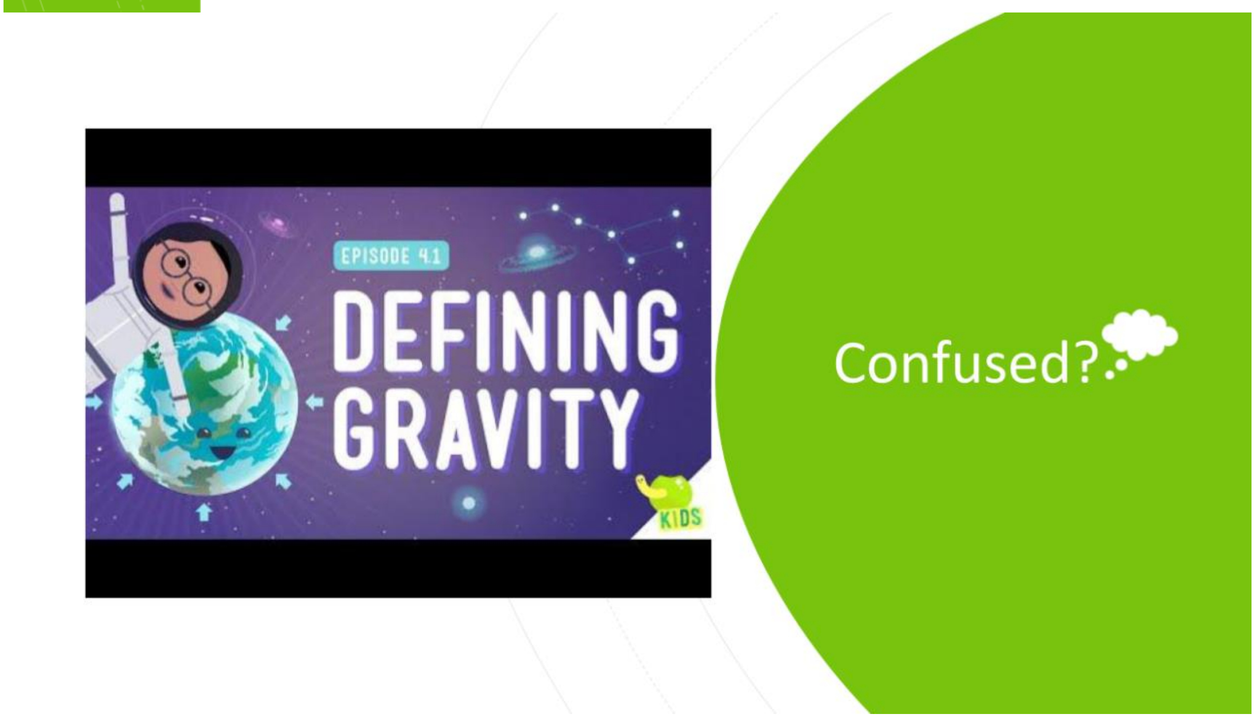
Vocabulary

Gravitational Force – The force exerted upon an object onto another object of larger mass

Mass – the total matter in an object; relates to how heavy and object can be

Now that you know…

- Which has a greater force of gravity?
  A. Paper clip + Magnet
  B. Paper clip + Earth
- From your answer what will the paperclip be pulled towards? The magnet or the Earth?
  - Distance can be ignored

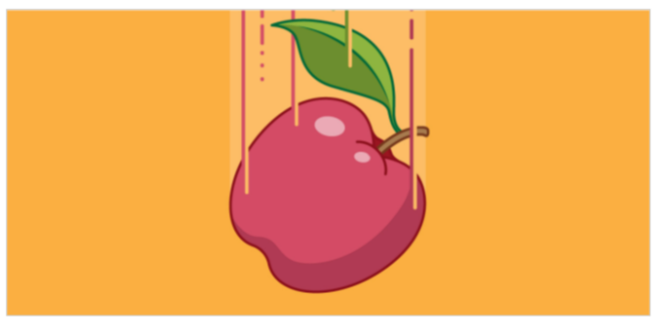


D1b. Gravity Guided Notes

Gravity

What is it?

What is gravity?

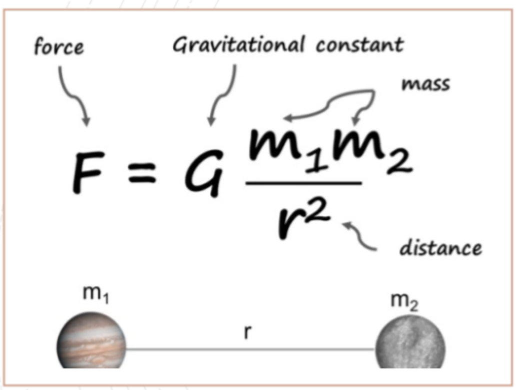


- Can you see it?
- Why do objects fall to the ground when we let go of them?
- Why do we land when we jump?

Gravity is…

a connection between space and matter

Gravity is…



- A [blank] that relates the interaction between objects with [blank]
  - The greater the mass the greater the force of gravity will be, inversely the smaller the mass the weaker the force of gravity will be
  - The smaller the distance the greater the force of gravity will be, inversely the greater the distance the weaker the force of gravity will be

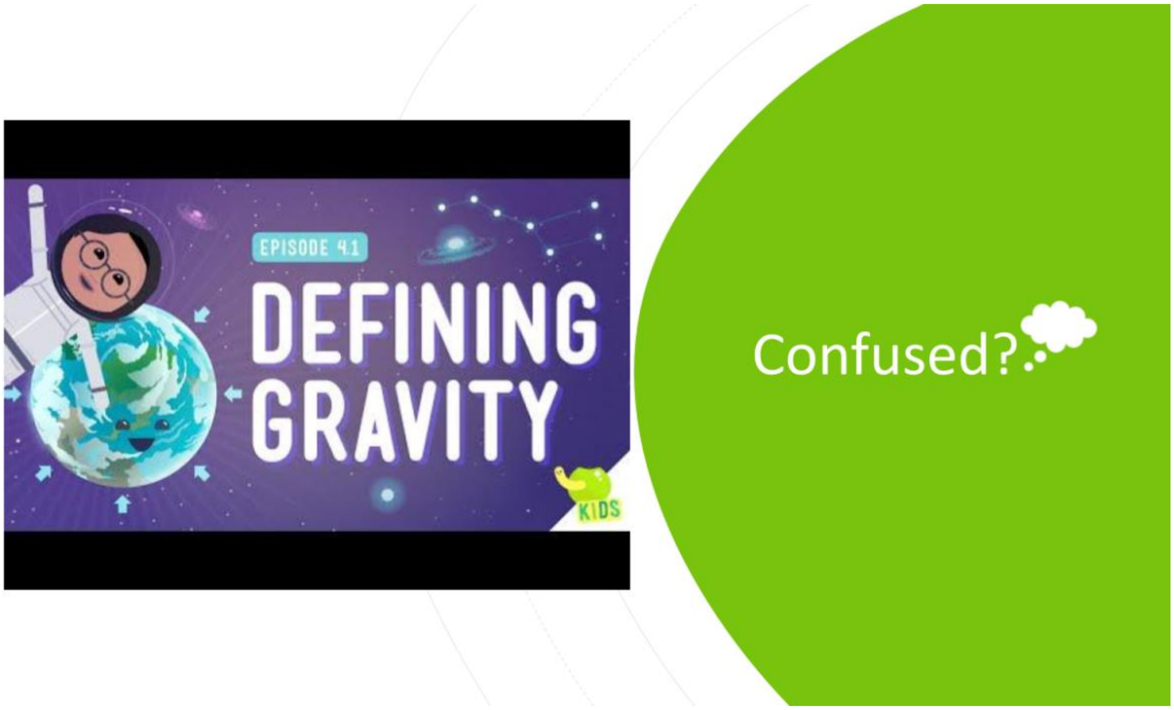
Vocabulary

Gravitational Force – The [blank] exerted upon an object from another object of [blank] mass

Mass – the total [blank]

Now that you know…

- Which has a greater force of gravity?
  - A. Paper clip + Magnet
  - B. Paper clip + Earth
- From your answer what will the paperclip be pulled towards? The magnet or the Earth?
  - Distance can be ignored



D1c. Paperclip & Magnet Handout

Activity

Today in class you get to play with gravity! Using what you've learned from magnet forces you will get to overcome the force of gravity on a paperclip as well as see how distance is a factor in how strong gravity is!

Your teacher will do this experiment in front of you and you should repeat the steps that they are doing. Make sure to follow along and ask questions if you are stuck or confused

1. Get a rod with paperclips tied to string dangling from it
2. Now move the rod around, point it up, point it down. Where do the paperclips end up pointing?
   a. This is the force of gravity enacted upon the paperclips due to the mass of earth and the very small distance between the paperclips and the Earth.

3. Place the rod underneath the magnet ruler that is held up by the books.

4. Bring the paper clips close enough to the magnets so that gravity is no longer pulling the paper clips to the ground.
    a. This can only work when the distance is very close between the two as the magnets won't pick up the paper clips from the ground. Why?

5. Repeat this with each magnet of varying strengths.
    a. The varying magnet strengths will show that the greater the force against gravity, the more distance paperclips can have between being affected by gravity and being affected by the magnet.

6. Watch the teacher have a heavier magnet in hand and demonstrate how the heavy magnet cannot attach to the other magnets. Why do you think this happens?
    a. This is due to the heavier magnet mass being affected by gravity more than the paperclips. Since gravity is related to the total mass of two objects. Earth + paperclip < Earth + Magnet thus gravity wins. (**This sub bullet will be on the professor's copy only)**

Worksheet

1. Now that the experiment is done and that you've seen what happens with the heavy magnet and the paperclips, talk **as a class** about why gravity is stronger in the case of the heavy magnet and why it is weaker in the case of the paperclip. What does distance have to do with this?

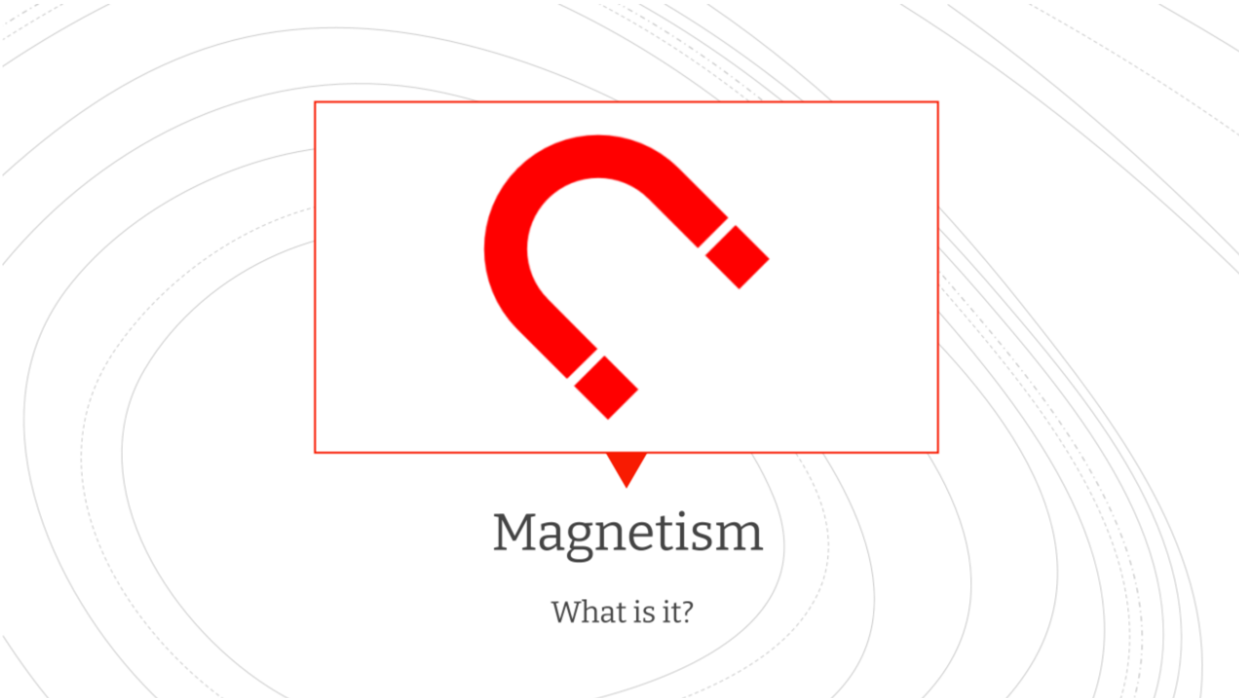
2. What factor could you change so the magnetic forces acting on the paperclip is greater than gravitational forces acting on the paperclip?

3. What if the paper clips were not magnetic? What would happen as you brought it further away from the ground?

4. In general, what do you think is stronger? Magnetic or gravitational forces?

5. With what you now know about the relationship of gravity in respect to mass and distance consider the following example: When a spaceship is launched, it must use a lot of thrust (force) to exit the atmosphere of Earth. Once it is out of the atmosphere of Earth, it can greatly reduce the thrust of the engines.
   a. Why must a great deal of thrust be used to exit the atmosphere?
   b. Why can the thrust be greatly reduced once it is out of the atmosphere?

D2a. Magnetism Powerpoint



Magnetism is…

- a force that can attract or repel certain objects
- something caused by the motion of electrically charged particles
- something we can't normally see
- related to electricity

Magnetism…

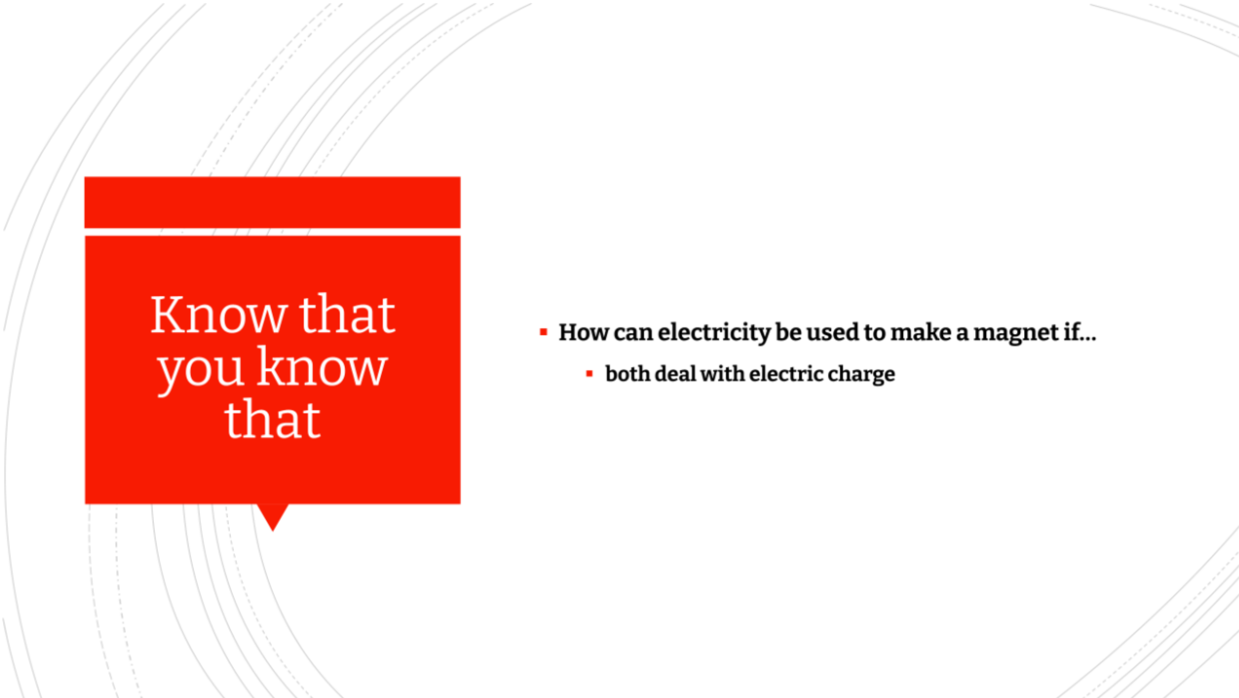
- has fields! Magnetic fields are created by electric charges moving
- also has poles! The poles on a magnet are the two points furthest away from the center of a magnet, there are two poles on a magnet
  - A north pole
  - A south pole
- A magnet can make some other metals, but ***not all*** metals, magnetic, the can be made from electric fields and can affect other electric fields as well

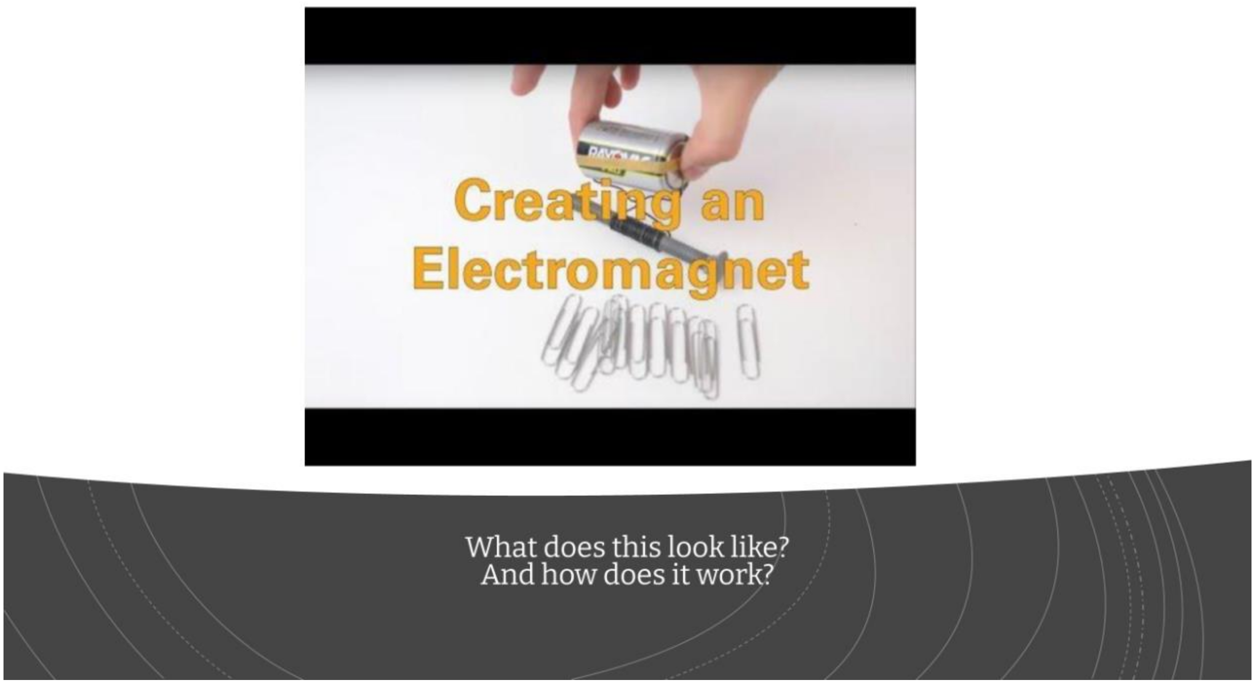
Magnetic Fields…

- can interact with one another
- are at the two poles of a magnet
  - When two of the same pole interact the fields will repel one another
    - Like two south poles of a magnet trying to interact
  - When two different poles interact the fields will attract one another
    - Like a north and south pole interacting with each other

Vocabulary

- Attraction – the force that acts between oppositely charged bodies, tending to draw them together
- Repulsion – the force that acts between likely charged bodies, tending to draw them away
- Force – an interaction that, when not challenged, will change the motion of an object
- Magnetic Poles – the two points of a magnet furthest from the center
- Magnetic Fields – the area around a magnetic material or a moving electric charge with which magnetic force acts





D2b. Magnetism Handout & Notes

Name:__________

Magnetism

Attraction and Repulsion with Magnets (Activity)

Now I know that we started off with this line of questioning before when talking about electricity, but we're going to ask those questions again just this time we're talking about magnetism. To do this we're going to ask you to try and push a magnet off a table using another magnet. Both of the small magnets you'll have should be the same, and you should have one magnet that's bigger than the other two.

1. Now take the two small magnets and place them so it balances off the end of the table, take the other small magnet and try to push the other magnet off of the table without either of the magnets touching each other. How close did you need to put the other small magnet in order for the first one to fall off the table?

2. Now repeat what you did but instead of using the two of the same sized magnets, use the big magnets and one of the small magnets. Place the big manget at the edge of the table and try to use the small magnet to push it off without touching the other magnet. How close did you have to get in order for the big magnet to fall off the table? Why did you think it wasn't the same distance as before?

3. Now do you think it would take the same amount of distance for you to pull the small magnet away from the end of the table using the other small magnet? How about if we tried to pull the big magnet away from the edge using the small magnet?

4. What about if we tried to pull the small magnet away from the edge of the table using the big magnet instead of the small magnet?

Guided Notes

Please complete this section while going over the presentation

1. If magnetism is a type of force, can you see it?

Yes or No

2. What is affected by magnets?

3. How is magnetism caused?

4. Two like poles interacting will cause a repulsive force

True or False

Magnetism interacting with Electricity (After Notes)

As we mentioned electricity and magnetism are related as magnetism is a result of a flow of electrons.

1. Using this information given, try and figure out how you'd construct an "electromagnet" using a small piece of metal which can carry electric charge, some wire, and a battery.

D2c. Electromagnet Simulation

Electromagnets and Force

(https://iwant2study.org/lookangejss/05electricitynmagnetism_21electromagnetism/ejss_model_EMStrengthpaperclips/EMStrengthpaperclips_Simulation.xhtml)

The goal of this simulation is to help visually show you how electromagnets work, and how electricity and magnetism are related. Before we begin please make sure that there's only one fully charged battery, there are three coils, and that the option of "Enable Data Logger" isn't checked off. From there, on the screen you'll see an "iron rod" that you'll be able to move once you hit the play button, and some paper clips at the bottom of the screen under the iron rod. Now that everythings been clarified, please follow the instructions below and record your findings in the dedicated sections.

Batteries

1. Hit the play button at the top of the screen, and move the iron rod down where the paper clips are, how many batteries were in the circuit? How many coils around the iron rod? How many paper

clips did you pick up? Make sure to be detailed in your data collection. Then repeat for the following settings

a. 2 Full Batteries & 3 Coils

b. 3 Full Batteries & 3 Coils

c. 4 Full Batteries & 3 Coils

d. 5 Full Batteries & 3 Coils

2. Now take the data you've collected and compile it into the following data table, make sure to remember to add proper labels.

3. From what you've done above, what can you conclude about the relationship between the amount of batteries and or voltage and magnetic force?

Click the “Reset” button, make sure that there’s only one full battery and only three coils.

Since you’ve analyzed the relationship between electricity and magnetism we’re now going to be looking at the relationship between the amount of coils, and or the amount of times we wrap the wire around the iron rod, and its effects on the resulting magnetic strength.

Coils

1. Hit the play button at the top of the screen, and move the iron rod down where the paper clips are, how many coils were there? How many batteries were in the circuit? How many paper clips did you pick up? Make sure to be detailed in your data collection. Then repeat for the following settings.

    a. 6 Coils & 1 Full Battery

    b. 9 Coils & 1 Full Battery

    c. 3 Coils & 1 Low Battery

    d. 6 Coils & 1 Low Battery

e. 9 Coils & 1 Low Battery

2. Now take the data you've collected and compile it into the following data table, make sure to remember to add proper labels.

Graphing

1. Now that you've organized your data, plot all the data you've collected on two different line graphs. One will show the amount of paper clips that the electromagnet will be able to pull up in relation to the amount of batteries and the other will show the amount of paper clips that the electromagnet will be able to pull up in relation to the amount of coils present. Below you'll find the link to an associated spreadsheet that you'll use to organize your data into a graph, you're going to have to download and make your own copy before you'll be allowed to input any data. Once done export your graphs here onto this google doc. (https://docs.google.com/spreadsheets/d/1h_UiUl9mz4OZkiELZUz1978gmWdyboCQOuPWcDiLF0k/edit?usp=sharing)

D3a. Electrical Fields Powerpoint

Electricity

What is it?

What is electricity?

- **Can you see it?**
- **Is it used everyday?**
- **How do we use electricity?**

Electricity is…

- a physical phenomena (something that we observe happens or exists)
- a type of energy
- something we can't normally see
- something that has charge caused by atomic particles (small things that make up everything, literally everything!)

Electricity has

- Charge! electric charge is determined by particles
  - There are two particles that have charge
    - Protons are positive
    - Electrons are negative

Electric Fields…

fill the space around charged particles

Protons create a positive field around it

Electrons create a negative field around it

can interact with each other

Two fields that have the same charge will repel one another

Two fields that don't have the same charge will attract one another

Vocabulary

Attraction – the force that acts between oppositely charged bodies, tending to draw them together

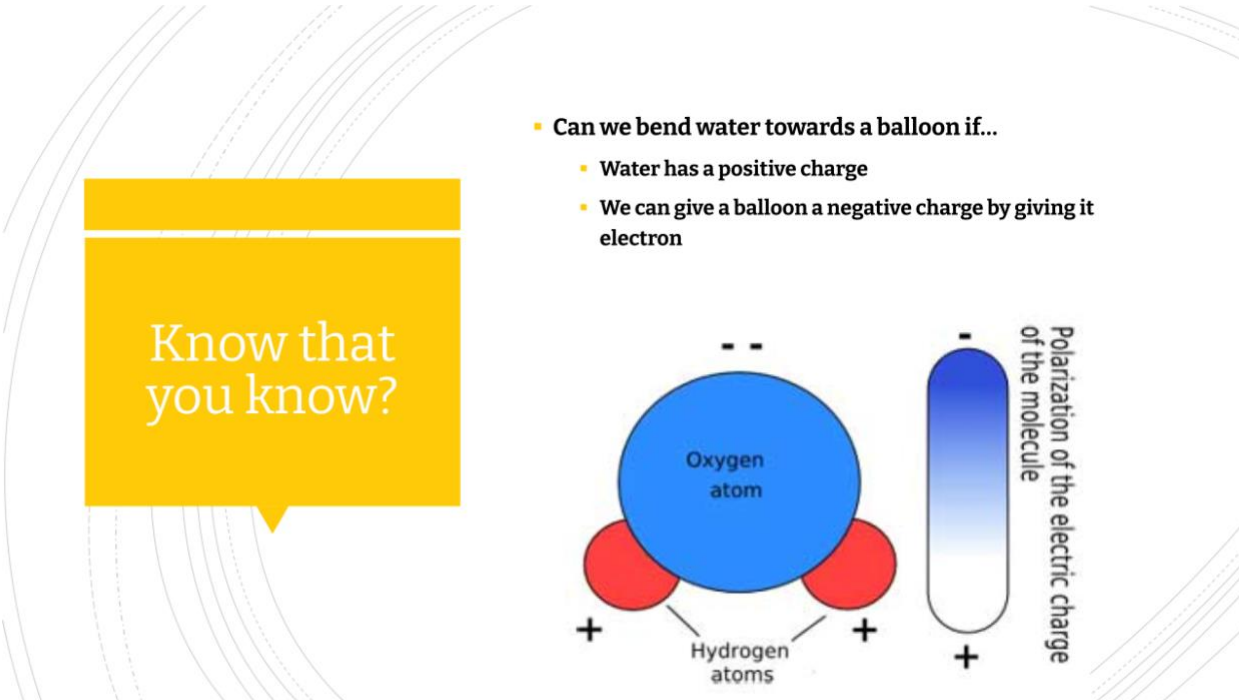
Repulsion – the force that acts between likely charged bodies, tending to draw them away

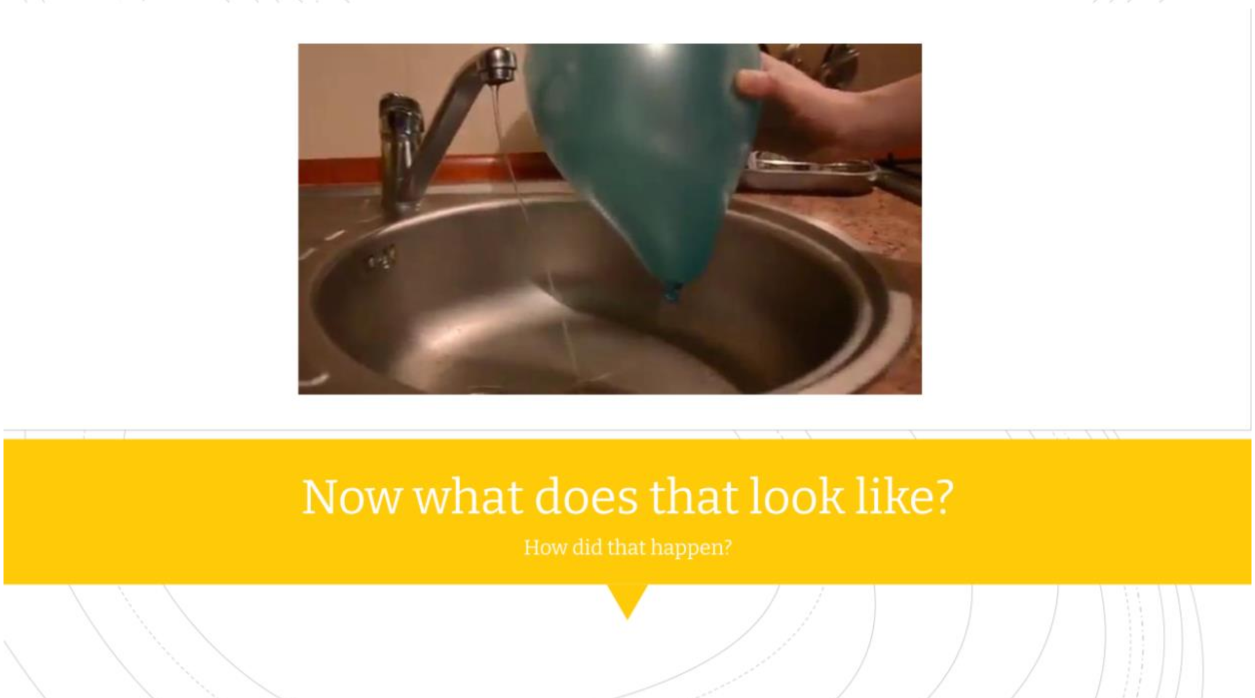
Positive – charge created from protons

Negative – charge created from electrons

Electric Charge – the basic property of matter that carries some basic particles that determine how an object will react in different fields

Electric Fields – the area around a charged particle or object with which a force would be pushed onto another charged particle or object





D3b. Electrical Fields Worksheet

Name:____________

Electricity

Attraction and Repulsion with a Balloon and a Sweater (Before Notes)

If opposites attract, then what happens when alike things interact?
We're going to ask you to rub a balloon against your chest and see if you can get it to stick to yourself.

1. What do you think is happening when you rub the balloon against your chest? (All answers are good answers!)

2. The balloon sticking to your chest is caused by an "attractive force". Now if we say opposites attract then what do you think is happening? What two things that are opposite from each other are causing this attraction?

Powerpoint Notes
Please complete this section while going over the presentation

1. If electricity is a physical phenomena, then can we see it?

Yes or No

2. What two particles determine electric charge?

3. What happens when two of the same type of field interact with one another?

Attraction and Repulsion with a Balloon and Water (After Notes)
Now that you've learned a bit more about the topic of electricity, electric charges, electric fields, and electrical force, try to answer these questions, and after that go back and try to correct your answers you gave prior to this. Just remember! Balloons like to uphold a negative charge because they can hold a lot of electrons! (Remember, electrons = negatively charged particles)

3. How do you think the balloon is directing the water without touching the water itself?

4. Is the water being moved based off of an attractive force or a repulsive force? Try to explain why it's attraction or repulsion refer back to differently charged particles.

D3c. Electrical Fields Simulation Handout

Balloons and Static Electricity

Online Simulation (https://phet.colorado.edu/sims/html/balloons-and-static-electricity/latest/balloons-and-static-electricity_en.html)

The goal of this simulation is to help visually show you how charges can move, and how charges can react with one another. Before we begin please make sure that the option to "Show all charges" is selected, and that there's only one balloon, all of these settings will be located towards the bottom of the screen. From there, on the screen you'll see a balloon, sweater, and a wall respectively, on each of the three items there will be red circles that have a "+'s" on them and blue circles with a "-'s" on them. These circles represent protons and electrons, with the red circles representing protons and the blue circles representing the electrons. Now that everythings been clarified, please follow the instructions below and record your findings in the dedicated sections.

Attraction

1. Take the balloon and drag it to the wall. What happens to the balloon? What happens to the protons and electrons? Does either of them move?

2. Now take the balloon and drag it over the sweater. What happens to the protons and electrons? Does either of them move?

3. Collect all of the electrons with the balloon and then bring the balloon so it's touching the wall. What happens to the electrons when you do this?

4. Now place the balloon onto the middle of the screen. What happens to the balloon then?

5. From what you've done above, what can you conclude about the relationship between electrons and protons?

Click the reset button at the bottom right hand side of the screen, and then select the option that shows two balloons, there should now be two balloons on the screen.

Repulsion

1. Take the green balloon and hover it over the sweater so it collects about half of the electrons that are located on the sweater, then place it so it's touching the wall. What happens to the electrons in the wall?

2. Proceed to do this again with the yellow balloon, place the yellow balloon so it's directly overlapping the green balloon on the wall, what happens to the electron in the wall after doing this?

3. Now, place the yellow balloon onto the sweater, once the yellow balloon is in place, move the green balloon to the middle of the screen and then quickly move the yellow balloon towards it. What happens to the green balloon?

4. Now using from what you've concluded above, what can you determine about the relationship between electrons?

D4a. Project Handout

The Design Board

You are an engineer at an automotive manufacturing company looking to determine how you can use technology involving fields of gravity, magnets, and electrically charged objects. You've determined the best way to do this is to design a car that can be easily modified. The basic components of each car are as such:

- Wide popsicle sticks
- Skewers & wheels
- Magnets (make sure the back of your car has the negative end attached to it)

You will make four cars. One car will only be composed of just the basic car and magnet. Then you are making two cars. A weighted magnetic car, an electromagnetic car, and a weighted electromagnetic car.

To make a weighted magnetic car:

1. Assemble 2 basic cars.
2. Place a moderately heavy washer disk on top of one car and tape it to secure it.
3. Leave your other basic car alone.

To make an electromagnetic car:

1. Assemble 2 basic cars
2. Place your 9V electromagnet on the car and tape it securely (no magnetic on this one)
3. Place your 2 9V parallel electromagnet on the car and tape it securely (no magnetic on this one)

Now that you've made all your cars it's time to prepare a straight, flat, level surface for your cars to race on! Once you've had a clearing, place your cars along the racing line and you will run two races.

The First Race

1. Place the basic car, and the two weighted magnetic cars on the line
2. Grab a magnet and everyone should hold the negative end of the magnet in place about 1 inch away from the back of the cars.
3. Let them repel away and then see how far they've gone.
4. Once the cars have stopped, hold your magnets in front of the cars with your negative and still facing the cars about 1 in away from the cars.
5. Observe how long it takes for each car to reach your magnet.
6. Repeat steps 2-5 until the finish line
7. Write down any observations you've had

The Second Race (electromagnet)

1. Place the basic car, and the two electromagnetic cars on the line
2. Grab a magnet and everyone should hold the south end of the magnet in place about 1 inch away from the north end of the electromagnet on the back of the cars.
3. Let them attract
4. Once the cars have progressed a reasonable amount, take a note on which electromagnet had a stronger attractions.
5. Repeat steps 2 and 3.
6. Observe how long it takes for each car to reach your magnet.
7. Repeat steps 2-5 until the finish line

8. Write down any observations you've had

Once you've recorded your results, go back to your desks and be prepared to prepare a project to present to your team about your findings.

<u>Bringing it all Together</u>

You must now present to your team a topic that covers this central idea: **What factors can you attribute to giving you the car that travelled the most distance?**

Some things that should be covered during your presentation are the following:

- What car seemed to travel the most distance over the shortest time in comparison to each race?
    - What about in comparison to all races?
- In this situation, what type of field plays the biggest role in making a car move fastest and what field made the car move the slowest?
    - Why do you think this? Is there any way that you can make the slowest moving car faster than the fastest moving car? Explain.
- Investigate the "bullet" train. Understand how it works and see if you can hypothesize a way to apply this for the race cars your company produces. Note that these race cars are solely meant to be driven on company racetracks, not public roads.
- With what you know so far, ask yourself how the fields involved can be used or are currently being used for something that affects you or affected society.

D4b. Project Rubric

Criteria	Exceeds (4)	Meets (3)	Some (2)	Little/None (0-1)
Quality of written Observations	- Winning & losing vehicle written down of each race - Winning & losing vehicle overall -Factors affecting the winning & losing cars -Why these factors affected the cars the way they did	- Winning & losing vehicle overall -Factors affecting the winning & losing cars	- Winning & losing vehicle overall	-Some observations written down however nothing regarding the fields involved or the winning and losing vehicles
Rating Vehicles (Presentation)	-Discusses What car seemed to travel the most distance over the fastest time in comparison to each race. -Winning and losing cars in comparison to all races. -Discusses the fields involved and how they produced the result seen	-Discusses What car seemed to travel the most distance over the fastest time in comparison to the overall race. -Discusses the fields	--Discusses What car seemed to travel the most distance	-No discussion/irrelevant discussion in regards to vehicle ratings

		involved and how they produced the results seen.	over the fastest time in comparison to the overall race.	
Applying the Bullet Train concept to your racecars	-Demonstrates a clear understanding on how the bullet train works -Provides an interesting way to apply bullet train concepts to the race cars -Provides an explanation on how the fields work on the bullet train concept -Provides an explanation of how the fields work on the proposed way to apply the bullet train concept to the race cars.	-Demonstrates a clear understanding on how the bullet train works -Provides an interesting way to apply bullet train concepts to the race cars -Provides an explanation on how the fields work on the bullet train concept	-Demonstrates a clear understanding on how the bullet train works OR -Provides an interesting way to apply bullet train concepts to the race cars OR -Provides an explanation on how the fields work on the bullet train concept	-Little/No relevant discussion about the bullet train, how it uses the fields discussed, and how to apply it to our race cars
Apply fields studied to society (Presentation)	-Provides an explanation and a unique way to use 2 or more of the fields discussed in class for societal benefit	-Provides an explanation and a unique way to use 1 of the fields discussed in class for societal benefit	-Provides a unique way to use 1 of the fields discussed in class for societal benefit BUT does not explain how the field would work in	-Provides no Unique way to use fields discussed for societal benefit

			their suggestion .	
Review & Critique Session	-Student attended session and took ALL feedback given into consideration and also gave their OWN feedback on how they felt the project was structured	-Student attended session and took ALL feedback given into consideration	-Student attended session and took some feedback into considerati on	-Student did not attend session
Presentation	-Student presented their project in an appropriate format and covered all expectations AND explained in depth how each field worked with each other to provide the results of each car that won/loss in each race + the overall race	-Student presented their project in an appropriate format and covered all expectations AND explained in depth how each field worked with each other to provide the results of the overall winner and loser	-Student presented their project in an appropriate format and covered some of the expectatio ns	-Student did not present their project.

Appendix E - Engagement Form, Attitude, and Aptitude Surveys

E1a. Engagement Form Lesson Plans Blank

Engagement Form

1. Did students comprehend, participate, and remain attentive greater than, less than, or about the same amount compared to a normal class period?

2. How was engagement across certain student demographics (male to female engagement)?
3. Did you feel like this class period was a success?

Please rate the comprehension, participation, attentiveness, engagement, and success rate on a scale of 1-5.

1 - Little to nothing
2 - Minimal
3 - Some / average
4 - Greater than average
5 - Exceeding average

1. Do students demonstrate an interest in the activity?
    a. Explain
    b. What demographic of students demonstrated the most interest, the least?

2. Do students demonstrate comprehension of the material during the activity through questions & statements?
    a. Explain
    b. What demographic of students demonstrated the most, the least?

3. Are students actively engaged in the powerpoint presentation?
    a. Explain
    b. What demographic of students showed the most engagement, the least?

4. How well are students responding to their online quiz & worksheet assignments?
    a. Major difficulties, or anything seeming too simple for them?
    b. How many students have approached you for help on these assignments?
    c. Student performance in respect to demographic data on assignments?

5. How excited were students to participate in the final project?
    a. How many students showed a lack of interest? Demographic?
    b. How clear/unclear was the act of going through the activity and explaining the final assignment to the students was?

6. Was there any consistent significant feedback from students during critique and review sessions received from students or observed?

7. How well does the lesson plans work given COVID restrictions?

a. How do the students feel about the unit being taught this way during COVID?
b. Anything significant you and the students would want to change/keep?

E1b. Engagement Form Project Blank

Engagement Form

1. Did students comprehend, participate, and remain attentive greater than, less than, or about the same amount compared to a normal class period?
2. How was engagement across certain student demographics (male to female engagement)?
3. Did you feel like this class period was a success?

Please rate the comprehension, participation, attentiveness, engagement, and success rate on a scale of 1-5.

1 - Little to nothing
2 - Minimal
3 - Some / average
4 - Greater than average
5 - Exceeding average

1. How excited were students to participate in the final project?
    a. How many students showed a lack of interest? Demographic?
    b. How clear/unclear was the act of going through the activity and explaining the final assignment to the students was?

2. Was there any consistent significant feedback from students during critique and review sessions received from students or observed?

3. How well does the lesson plans work given COVID restrictions?
    a. How do the students feel about the unit being taught this way during COVID?
    b. Anything significant you and the students would want to change/keep?

E1c. Engagement Form Electromagnetism Blank

Engagement Forms

1. Did students comprehend, participate, and remain attentive greater than, less than, or about the same amount compared to a normal class period?

2. How was engagement across certain student demographics (male to female engagement)?
3. Did you feel like this class period was a success?

Please rate the comprehension, participation, attentiveness, engagement, and success rate on a scale of 1-5.

1 - Little to nothing
2 - Minimal
3 - Same / average
4 - Greater than average
5 - Exceeding average

1. Do students demonstrate an interest in the activity?
   a. Explain
   b. What demographic of students demonstrated the most interest, the least?

2. Do students demonstrate comprehension of the material during the activity through questions & statements?
   a. Explain
   b. What demographic of students demonstrated the most, the least?

E1d. Engagement Form Gravity

Please rate the comprehension, participation, attentiveness, engagement, and success rate on a scale of 1-5.

1	2	3	4	5
Little to nothing	**Minimal**	**Same/Average**	**Greater than Average**	**Exceeding Average**

1. Did students comprehend, participate, and remain attentive greater than, less than, or about the same amount compared to a normal class period?	**3**
2. How was engagement across certain student demographics (male to female engagement)?	**3**
3. Did you feel like this class period was a success?	**4**
4. Do students demonstrate an interest in the activity? **a. Explain** **b. What demographic of students demonstrated the most interest, the least?**	**A: all students were actively experimenting with the paperclips and magnets, trying to pull the paperclips up against gravity.** **B: No differences seen between male/female or any other demographic.**
5. Do students demonstrate comprehension of the material during the activity through questions & statements? **a. Explain** **b. What demographic of students demonstrated the most, the least?**	**A: In class, students demonstrate complete understanding of the relationship between opposite and like charges. But the remote students do not show as complete understanding. But I think it is more due to their writing ability - they struggle expressing themselves clearly in writing.** **B: No differences seen between male/female or any other demographic. The differences are seen between remote and in person students. In person, students complete the work but when remote, students struggle and do not always use my support videos.**

6. Are students actively engaged in the PowerPoint presentation? **a. Explain** **b. What demographic of students demonstrated the most, the least?**	**A: all students completed the guided notes.** **B: No differences seen between male/female or any other demographic. The differences are seen between remote and in person students. In person, students complete the work but when remote, students struggle and do not always use my support videos.**
7. How well are students responding to their online quiz & worksheet assignments? **a. Major difficulties, or anything seeming too simple for them?** **b. How many students have approached you for help on these assignments?** **c. Student performance in respect to demographic data on assignments?**	**A: None** **B: In person students ask for help often. The remote students use the support videos. If they do not use the videos, they struggle with completing the work.** **C: No differences seen between male/female or any other demographic. The differences are seen between remote and in person students. In person, students complete the work but when remote, students struggle and do not always use my support videos.**

E1e. Engagement Form Electricity

Please rate the comprehension, participation, attentiveness, engagement, and success rate on a scale of 1-5.

1	2	3	4	5
Little to nothing	Minimal	Same/Average	Greater than Average	Exceeding Average

1. Did students comprehend, participate, and remain attentive greater than, less than, or about the same amount compared to a normal class period?	**3**
2. How was engagement across certain student demographics (male to female engagement)?	**4**
3. Did you feel like this class period was a success?	**4**
4. Do students demonstrate an interest in the activity? **a. Explain** **What demographic of students demonstrated the most interest, the least?**	**A: The kids loved the demonstrations with the balloons and were very engaged.** **B No differences seen between male/female or any other demographic. The differences are seen between remote and in person students. In person, students complete the work but when remote, students struggle and do not always use my support videos.**

5. Do students demonstrate comprehension of the material during the activity through questions & statements? **a. Explain** **b. What demographic of students demonstrated the most, the least?**	**A: In class, students demonstrate complete understanding of the relationship between opposite and like charges. But the remote students do not show as complete understanding. But I think it is more due to their writing ability - they struggle expressing themselves clearly in writing.** **B: No differences seen between male/female or any other demographic. The differences are seen between remote and in person students. In person, students complete the work but when remote, students struggle and do not always use my support videos.**
6. Are students actively engaged in the PowerPoint presentation? **a. Explain** **b. What demographic of students demonstrated the most, the least?**	**A: Yes, when students are in person in class. But when given as a remote assignment, many students did not complete the guided notes.** **B: No differences seen between male/female or any other demographic. The differences are seen between remote and in person students. In person, students complete the work but when remote, students struggle and do not always use my support videos.**

7. How well are students responding to their online quiz & worksheet assignments? **a. Major difficulties, or anything seeming too simple for them?** **b. How many students have approached you for help on these assignments?** **c. Student performance in respect to demographic data on assignments?**	**A: None** **B: In person students ask for help often. The remote students use the support videos. If they do not use the videos, they struggle with completing the work.** **C: No differences seen between male/female or any other demographic. The differences are seen between remote and in person students. In person, students complete the work but when remote, students struggle and do not always use my support videos.**

E1f. Engagement Form Magnetism

Please rate the comprehension, participation, attentiveness, engagement, and success rate on a scale of 1-5.

1	2	3	4	5
Little to nothing	Minimal	Same/Average	Greater than Average	Exceeding Average

1. Did students comprehend, participate, and remain attentive greater than, less than, or about the same amount compared to a normal class period?	**3**

2. How was engagement across certain student demographics (male to female engagement)?	**3**
3. Did you feel like this class period was a success?	**4**
4. Do students demonstrate an interest in the activity? **a. Explain** **b. What demographic of students demonstrated the most interest, the least?**	**A: Yes, in class students enjoyed working with the magnets and asked great questions and did their own experiments.** **B No differences seen between male/female or any other demographic. The differences are seen between remote and in person students. In person, students complete the work but when remote, students struggle and do not always use my support videos.**
5. Do students demonstrate comprehension of the material during the activity through questions & statements? **a. Explain** **b. What demographic of students demonstrated the most, the least?**	**A: Yes, students are engaged when they are in class.** **B: No differences seen between male/female or any other demographic. The differences are seen between remote and in person students. In person, students complete the work but when remote, students struggle and do not always use my support videos.**

6. Are students actively engaged in the PowerPoint presentation? **a. Explain** **b. What demographic of students demonstrated the most, the least?**	**A: Yes, students are engaged when they are in class. But these guided notes were done remotely on a Wednesday. That is why the average grade is so low, many students were absent for this remote learning.** **B: No differences seen between male/female or any other demographic.**
7. How well are students responding to their online quiz & worksheet assignments? **a. Major difficulties, or anything seeming too simple for them?** **b. How many students have approached you for help on these assignments?** **c. Student performance in respect to demographic data on assignments?**	**A: None** **B: In person students ask for help often. The remote students use the support videos. If they do not use the videos, they struggle with completing the work.** **C: No differences seen between male/female or any other demographic. The differences are seen between remote and in person students. In person, students complete the work but when remote, students struggle and do not always use my support videos.**

E1g. Engagement Form Electromagnetism

Please rate the comprehension, participation, attentiveness, engagement, and success rate on a scale of 1-5.

1	2	3	4	5
Little to nothing	Minimal	Same/Average	Greater than Average	Exceeding Average

1. Did students comprehend, participate, and remain attentive greater than, less than, or about the same amount compared to a normal class period?	**3**
2. How was engagement across certain student demographics (male to female engagement)?	**3**
3. Did you feel like this class period was a success?	**4**
4. Do students demonstrate an interest in the activity? **a. Explain** **b. What demographic of students demonstrated the most interest, the least?**	**A: all students enjoyed both the hands-on lab and the simulation. In class students had fun changing the number of coils and/or batteries and seeing the effect on the strength of the electromagnet.** **B: No differences seen between male/female or any other demographic.**
5. Do students demonstrate comprehension of the material during the activity through questions & statements? **a. Explain** **b. What demographic of students demonstrated the most, the least?**	**A: the students understand the relationship between number of coils or number of batteries and strength of the electromagnetic. They understand that the electric current creates the magnetic field.** **B: No differences seen between male/female or any other demographic.**

E1h. Engagement Form Final Project

Please rate the comprehension, participation, attentiveness, engagement, and success rate on a scale of 1-5.

1	2	3	4	5
Little to nothing	**Minimal**	**Same/Average**	**Greater than Average**	**Exceeding Average**

1. Did students comprehend, participate, and remain attentive greater than, less than, or about the same amount compared to a normal class period?	**4**
2. How was engagement across certain student demographics (male to female engagement)?	**No differences**
3. Did you feel like this class period was a success?	**Yes, the final project was a success**
4. How excited were students to participate in the final project? **a. ALL students loved the final project. They enjoyed every aspect of the project, especially the data collection (racing the cars). They enjoyed problem solving. They had to figure out how to hold the magnets to get the best repulsive force.** **b. How clear/unclear was the act of going through the activity and explaining the final assignment to the students was?**	**A: ALL students loved the final project. They enjoyed every aspect of the project, especially the data collection (racing the cars). They enjoyed problem solving. They had to figure out how to hold the magnets to get the best repulsive force.** **B: The instructions were very clear**

5. Was there any consistent significant feedback from students during critique and review sessions received from students or observed?	**Students struggled with explaining how the maglev train works. Even when given sources, they struggled with reading and understanding what they read. This is not related to the design of the project; I feel this is a bigger issue in general. Students rely more on visuals rather than decoding written information to gain knowledge.**
6. How well does the lesson plans work given COVID restrictions? **a. How do the students feel about the unit being taught this way during COVID?** **b. Anything significant you and the students would want to change/keep?**	**A: I felt that the simulations were perfect for COVID instruction. But when remote, many students so not complete any work, even though the work is engaging and interesting.** **B: N/A**

E2. Attitude Survey

Pre & Post Attitude Check

How do you feel about the topics at hand?

* Required

Overall Attitude/Confidence Check

1. Do you like Science *

1 point

a. Yes
b. No

1a. If you answered yes, please explain why *

1b. If you answered no, please explain why *

2. Do you think we use science daily? *

a. Yes
b. No

3. What do you think your strong points are academically? (ie: science, math, reading, writing, etc...) *

4. What do you think would make you more confident in terms of being able to understand the material better? *

5. How confident are you when it comes to learning new things? *

a. Very Confident
b. Somewhat Confident
c. Not Confident

6. How well do you think you understood the material given? (Answer, "TBD" if the new lesson plan has yet to be given) *

a. Very Well
b. Ok
c. Kinda Confused
d. Completely Lost
e. TBD

E3. Aptitude Survey

Pre & Post Content Assessment

* Required

A. Electricity

Answer these questions to the best of your ability, this is not graded.

1. What is electricity and what gives it it's charge? *

2. Select everything that Electrical fields can do *

a. Fill Space around Charged Particles
b. Interact with each other
c. Can be used to repel or attract two objects without touching
d. All of the above
e. None of the above

3. In terms of electricity, what is attraction and repulsion?

B. Magnetism

Answer these questions to the best of your ability, this is not graded.

1. How do magnets attract or repel objects without touching them?

2. What do you call the area that a magnetic force exists in?

a. Magnetic field
b. Attractive field
c. Empowering Field

3. In your own words, describe how attraction and repulsion work in magnets.

C. Gravity

Answer these questions to the best of your ability, this is not graded.

1. In your own words, describe what gravity is.

2. Why do we land back on the ground when we jump?

3. How does distance relate to gravity? (Read carefully!)

a. The further two objects are to each other, the greater the force of gravity becomes.
b. The closer two objects are to each other, the greater the force of gravity becomes.
c. The closer two objects are to each other, the lesser the force of gravity becomes.
d. The further two objects are to each other, the lesser the force of gravity becomes.

4. Why do you think that when you jump on the moon, you can jump higher than what you could jump on earth?

Appendix F - Student Work

Final Project
Watch this video first.

Name:

The Design Board

You are an engineer at an automotive manufacturing company looking to determine how you can use technology involving fields of gravity, magnets, and electrically charged objects. You've determined the best way to do this is to design a car that can be easily modified. The basic components of each car are as such:

- Wide popsicle sticks
- Lego wheels and axles
- Magnets (make sure the back of your car has the north end attached to it)

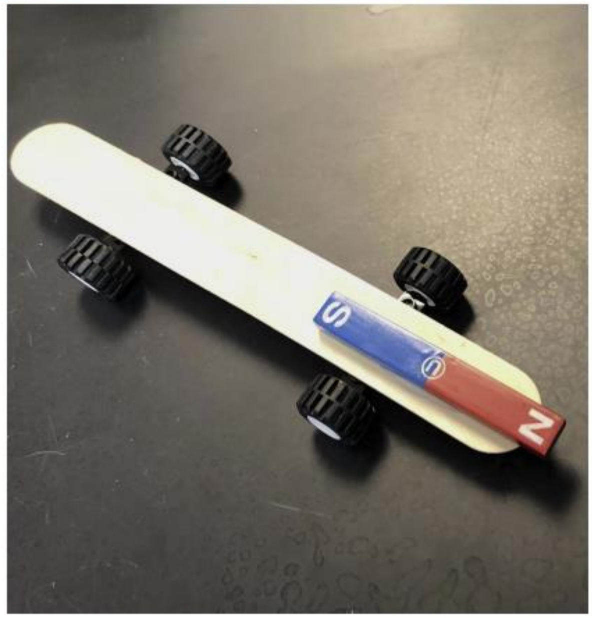
Your goal: To have your car travel 5 meters in the shortest amount of time.

The Basic Car: How can you make it move?

Look at the picture of the basic car. The back of the car has a magnet with the north pole of the magnet pointing toward the back of the car.

With what you have learned about fundamental forces, how can you make this car move forward to win a race without touching the car? Explain.

I would use another magnet. I would use another magnet to attract to the car by using the north end of the magnet to pull the car. But the north is the back end of the car. So you would use the north end of another magnet to PUSH the car?



The First Race: Effect of Mass on Speed

1. Place the basic car and the weighted magnetic car on the starting line
2. Use a magnet and hold the north end of the magnet in place about 1 inch away from the magnet on the back of the cars.
3. Let the cars repel away from your magnet and observe the distance traveled.
4. Once the cars have stopped, hold your magnets in front of the cars with your north end still facing the cars about 1 in away from the cars.
5. Observe how long it takes for each car to reach your magnet.
6. Repeat steps 2-5 until the finish line
7. Write down all observations and record the time it takes for each car to reach the finish line in the data table.

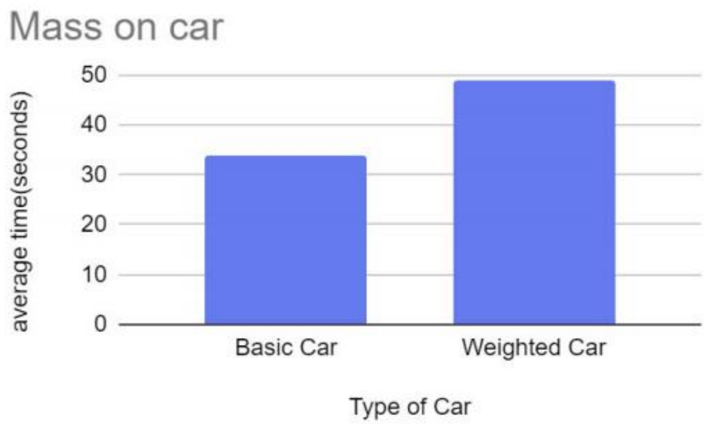
Table 1: Effect of Mass on Speed

	Time (s)			
Type of Car	**Group 1**	**Group 2**	**Group 3**	**Group 4**
Basic Car	20	16	70 No, 45	29No, 94
Weighted Car	67	23	56No, 78	49No, 82

Record all observations here:
I observed that you had to hold the magnet at an angle to make the car go straight.

Graph 1: Effect of Mass on Speed

Insert a graph of the data here:



Bringing It All Together: Analysis

Which car was the fastest and why was it the fastest? What factors caused it to be the fastest car?

Analysis Questions:

1. What car seemed to travel the most distance over the shortest time in each race?
   In three of the four trials the basic car seemed to travel the most distance over the shortest time because there was less friction.
2. What about in comparison to all races?
   The basic car moved faster three times out of the four trials.
3. What type of field plays the biggest role in making a car move fastest and what field made the car move the slowest
   The weighted car had more friction so it went slower which is gravity. Magnetism made the car move faster.
4. Why do you think this? Is there any way that you can make the slowest moving car faster than the fastest moving car? Explain.
   Yes, if you took more weight off the slower car it would make the car move faster. We were using a repulsive force, So we could use a stronger magnet or use a different wheels to reduce the friction. Excellent.

Bringing It All Together: Analysis Continued

Analysis Questions:

5. Investigate the "bullet" train. Understand how it works and see if you can hypothesize a way to apply this for the race cars your company produces. Note that these race cars are solely meant to be driven on company racetracks, not public roads.
The bullet trains are used by magnets repelling the train to push the train upwards. Then they use both north and south poles to push the car forward. So you would need to make a guideway that attracts and repel the train to move up and forward.
6. With what you know so far, ask yourself how the fields involved can be used or are currently being used for something that affects you or affected society.
Electromagnets are used in everyone's everyday life. For example there uses in speakers, microphones telephones

Grading Rubric

Rubric Categories	Great, 12	Good, 8	Needs More, 4	Not Ready, 0
Data Tables and Observations	- Data table entries are accurate, complete and clear -The winning and losing vehicle is clearly identified for each race in the observations - The winning and losing vehicle overall is clearly identified in the observations	- Data table entries are mostly accurate, complete and clear -The winning and losing vehicle is clearly identified for each race in the observations	- Data table entries are mostly accurate, complete and clear - The winning and losing vehicle overall is clearly identified in the observations	Few entries are made in the data table and few observations are written.
Graphs	Graphs are accurate, complete and clear for each race (axes labels, title, data points)	Graphs are mostly accurate, complete and clear for each race (axes labels, title, data points)	Graphs are somewhat accurate, complete and clear for each race (axes labels, title, data points)	Graphs are missing - are minimally accurate, clear and complete.
Analysis Questions 1-4	Responses are clear, accurate and complete and include specific details: -Discusses what car seemed to travel the most distance over the fastest time in comparison to each race. -Winning and losing cars in comparison to all races. -Discusses the fields involved and how they produced the result seen	Responses are mostly clear, accurate and complete and include most of the specific details: -Discusses what car seemed to travel the most distance over the fastest time in comparison to each race. -Winning and losing cars in comparison to all races. -Discusses the fields involved and how they produced the result seen.	Responses are somewhat clear, accurate and complete and include some specific details: -Discusses what car seemed to travel the most distance over the fastest time in comparison to each race. -Winning and losing cars in comparison to all races. -Discusses the fields involved and how they produced the result seen.	Responses are minimally clear, accurate and complete and include few specific details: -Discusses what car seemed to travel the most distance over the fastest time in comparison to each race. -Winning and losing cars in comparison to all races. -Discusses the fields involved and how they produced the result seen
Analysis Questions 5-6	Responses are clear, accurate and complete and include specific details: -Demonstrates a clear understanding on how the bullet train works. -Provides an interesting way to apply bullet train concepts to the race cars -Provides an explanation and a unique way to use 2 or more of the fields discussed in class for societal benefit	Responses are mostly clear, accurate and complete and include most specific details: -Demonstrates a clear understanding on how the bullet train works. -Provides an interesting way to apply bullet train concepts to the race cars. -Provides an explanation and a unique way to use 2 or more of the fields discussed in class for societal benefit	Responses are somewhat clear, accurate and complete and include some specific details: -Demonstrates a clear understanding on how the bullet train works. -Provides an interesting way to apply bullet train concepts to the race cars. -Provides an explanation and a unique way to use 2 or more of the fields discussed in class for societal benefit	Responses are minimally clear, accurate and complete and include few specific details: -Demonstrates a clear understanding on how the bullet train works. -Provides an interesting way to apply bullet train concepts to the race cars. -Provides an explanation and a unique way to use 2 or more of the fields discussed in class for societal benefit

Appendix G - Interview Form

1. How did everything go overall?	**Everything went great, "perfect lesson plan", good job providing base information, simulations were really well + hands on activity.** **Simulation (sweater and balloon) really instilled the electron attractions into the kids understanding, kids understood the "doubling effect".**

2. What were some key struggles you had encountered in person & virtually throughout the unit?	**Students were responsive to the critical thinking questions when in a hands-on environment in class (can you make paper clips oppose gravity)** **At home tasks were only partially completed which caused averages to drop** **o Kids would not zoom into livestream.** **o Remote work was difficult as kids would not show up/do the work.** **Final project electromagnet car, design & instructions did not let it work.**

3. What were some key struggles students had in person & virtually throughout the unit?	**Students would not do online work.** **Fundamental forces - understood the basic concepts (opposites attract, etc.), forces act on objects (pushing/pulling was simplified to them as that), they fully understand that you cannot see these forces.** **kids struggled with vocabulary, understanding what the question is asking but understood how to answer it well once the question was cleared up for the kids.** ● **Generally speaking, kids struggle with analysis questions.** ● **Electromagnetism was pretty confusing to them they struggled to understand with why an electromagnet works when you use a nail and wrap a wire around it.** **Professor made demonstration videos for activity instructions because ~50% students struggled to understand only written instructions from activities (done in general not just the unit)** ● **Done for all online activities but not in person.**

4. Do you believe that some students demonstrated an interest in STEM that will carry on beyond this unit? If so, how many?	**Yes, students loved magnets & electromagnets activity, balloon and water, made a student want to do their science project on electromagnets (How type of wire affects electromagnet strength)** **"All students loved all hands on", many kids asked professor after the unit to continue to use magnets in their education.**

5. How did critique sessions go on the project?	**Students did not understand bullet train due to only reading being assigned, had to find alternate sources (videos, visuals, etc.) than provided on how the bullet train work. Had to read article with them.** **For question in regard to bullet train most kids did not answer the question/did not show comprehension** **Last question about fields used in real life, some kids left it blank, some kids actually did it and provided their own information and presented it.** **Some kids left it blank because they did not want to research a real-life application and present it possibly because it was too vague (given a search criterion to help them find their own application).** **Reading dense parts/parts where students had to be “self-starting” were where students struggled the most.**

6. How well did students collaborate together?	**Students collaborated together to analyze the class data on the races, discussed ways to improve cars together, kids wanted to collaborate a lot on magnet activity they understood the effect of the range of magnetic effects on magnetic strengths (worked alone for this part)** **Even for parts where they were working alone, students asked each other questions and collaborated.** **Overall, students collaborated very well on all aspects.**
7. What were all the ways students present their final projects?	**Due to limited supplies, due to time constraints, Professor gave students a template to present their final project.** **"I'm not sure if not given a template, they would've known what to put together".**
8. How well were students able to relate the unit in a way that affects society/themselves?	**Half the students were able to do it well, about the other half did not do it, or struggled.**

9. **Do you have test scores from the previous year where PBL was not employed? If so, can you send us the averages?**	**No because the Professor usually does not teach without incorporating some aspect of PBL.** **Magnetism quiz average: 75.4%**
10. Any discernible difference amongst demographics (ages, gender, ESL, primary English speaker, etc.)	**No, online work completion was difficult but in person work was good.**
11. Is there anything that should have been done differently?	**Good unit will be sharing with the whole department because of how well it adapted and fit well, and students received it very well.**