Creating An Inquiry-Based Force Unit For A Ninth-Grade Science Class

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Creating an Inquiry-Based Force Unit for a Ninth-Grade Science Class

by

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A final paper submitted in partial fulfillment of the requirements for the degree of Master of Arts in Teaching

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August 2017

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“When you make the finding yourself
even if you're the last person on Earth to see the light
you'll never forget it.”
-Carl Sagan
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Chapter One

Introduction

I have always loved science. Throughout my years of being a student and a teacher, I have found that this is not true for all students. In fact, many students do not like the subject. Some students come in with the preconceived notion that they are not good at science. Because of this, making a science class interesting and meaningful to all students is important. Learning science involves more than just knowing facts and figures. Students need to learn how to be critical thinkers, like a scientist. Scientists do not exclusively know an assortment of facts about a topic, rather, they know how to ask questions and draw conclusions based on data, observations, and evidence. Having been exposed to this type of teaching, where I am required to think critically about what I am learning, at different points in my life has shown me the importance of it. For this project, I will be exploring the question: How might student achievement be supported through inquiry-based teaching? To explore this question, I will be creating a unit on forces utilizing the Understanding by Design framework to help me structure the sequence.

My Time As A Student

In high school I was a diligent student who very much enjoyed studying science. As a result, I did well in the class and worked hard to understand the concepts and ideas. A lot of the learning was memorizing facts and figures and how they related to our lives. Although the scientific method was a concept that was taught and discussed, there was very limited application of the method throughout the courses. When it came time to do a lab, the instruction and methodology were all laid out for us to follow along. Not much thought was
required. As long as I followed the steps, I would get the required results. Often, I already knew the results I was expecting as we had talked about it in class. Through these experiences, I learned the scientific method in theory but never really had a chance to be a true scientist in a science classroom. Because I had not experienced any other teaching methods, I was fine with this way of studying science, but I later learned that this was not truly studying science.

My experience changed when I went to college. Being interested in science, I took many science classes right from the start. In these classes, many of the labs and activities I did were not directly laid out for me. Instead, an idea or question was presented and we were asked to develop a way to answer that question. There was definitely assistance from the professor in the beginning as it was clear that a lot of us had not done science in this way before. Through this process, we had to work together to think about ways to answer the questions. This included coming up with experiments we wanted to try. Before we did any experiments, we would have to be able to explain why we were going to do them. This required us to think critically about what variables might be affecting a phenomenon in question. Once the variables were identified, next was determining a way in which to test them. An example of one of these projects was for a geology class in which I was tasked with finding the three best locations to drill wells on a plot of land. This required me to come up with criteria that would allow me to determine if a location was a good or bad fit for a well. I then would use the resources given to me: topographic maps, aerial photos, and maps of bedrock cross-sections, to determine what I thought were good locations for wells. This project, and others like it, allowed me to test ideas and discuss them with others. Many times, I would find that an idea would not work, but I would learn from that to improve
upon my next hypotheses. Many of these teachers who assigned this type of work became inspiration for the type of teacher I hope to be.

My Time As A Teacher

During my first three years of teaching high school science, it was abundantly clear that not every student is interested in studying science. This is completely understandable as most of them will not become scientists or follow a career path that requires the use of much science. But this does not mean that they should not learn science. As a science teacher, I believe my role is to prepare students to be scientists, for those who will take that path, and to create well-rounded, critically-thinking citizens of all students.

When coming into my first teaching position, the class I taught already had a fairly well defined curriculum to follow. There was room for small changes but a lot of the activities and labs were already set. This was a nice way to start teaching as I was able to have a curriculum to build off of, but it did not always seem the best for engaging the students or teaching them about the nature of science. Many of these activities and labs were worksheets in which the students followed them step-by-step, similar to what I experienced in high school. There was no need for them to think critically about how they would set up the lab or draw conclusions from their data as it was all laid out for them. Many times, the students already had an idea of what they were going to see in the activity. This approach seemed to be a good way for the students who were already interested in science, much like me when I was a high school student, to learn some facts and figures about different topics. For everyone else, they are able to memorize these same facts and figures in order to do well on the test and then forget about them.
In the school where I currently teach, students are extremely focused on maintaining excellent grades. They are continually working to find out how they can get and keep an A in any class. Many of them are very comfortable with the routine of coming to class, taking notes, doing a worksheet, studying for a test, and then repeating. This is mostly just memorization of material that they quickly forget once they have taken the final assessments. Many of the students feel uncomfortable when this routine is not followed, as it is what they are used to.

Not all of the activities the students did in my science class were these cookbook labs. One less prescribed and more exploratory activity was when the students had to design, build, and program a robot. Some examples of projects they could design and develop were mini elevators, grocery store conveyor belts, and skee-ball machines. In these activities, the students had to work together in a group, be creative, test and retest ideas, and ultimately come up with their own design. Many of the students struggled with this process, as it was not as cut and dry as they were used to. Even when I expressed to them that I was interested in seeing the process that they were going through as opposed to them having a final product, most students could only fixate on having that final working product. In hopes to achieve this, students were always asking for hints before they tried out any ideas of their own. They had the idea of following a set of instructions to build their specific device as opposed to working with their partners to design and build it on their own.

Upon reflection of the last three years, I need to create more opportunities for my students to be critical thinkers. I need to find ways for them to develop their own labs and determine how they can answer their own questions. Posing questions about a concept to
students that they need to solve, as opposed to just having them experience the concept. By incorporating this more, I would hope that the students would become more comfortable with this format and allow themselves to move out of their comfort zones.

**Why This Is Important**

For high school students, or anyone, to learn science, they need to learn about the nature of science as opposed to memorizing facts, figures, and laws. While it is helpful to have at least a basic understanding of science concepts, understanding *how* science is done is even more powerful. Many schools are teaching students facts without teaching how science is done. This results in students who can pass a test but may not be critical thinkers. Learning about science is much more than just knowing facts. Instead, learners should discover more about knowing how to look at an argument or scientific discovery critically. To do this, students need to know how science is done. They need to understand that a hypothesis does not have to be true. As well, they need to grasp that the results from a single study do not mean that the particular question has been definitively answered. The students need to look at this information critically. Was the experiment done properly and ethically? By knowing how to look for these things allows students to become critical thinkers about science.

In order to reach this level of understanding about science the learner must experience it. Providing students with opportunities to ask a question and then find a way to seek their own answer provides a much more meaningful experience for them. Through careful planning, a lesson can be designed to provide students with the appropriate scaffolding to ask a question about the physical world around us. Then, by providing the necessary tools, they can go out and explore the topic. By giving these students this type of
experience in school, where they have support from teachers and peers, they can grow more comfortable with the idea of searching for their own understanding. This will provide them with a tool much more powerful than having any physical law memorized as they will be able to go out and answer questions when they have them. This is where teaching through inquiry can play a pivotal role in helping students do science, not just learn about science.

**Unit Design**

To explore my question, I am going to be designing an inquiry-based unit introducing forces. Whether students realize it or not, we all experience forces every moment of our lives. Forces are a fundamental phenomenon in our natural world. Because of this, students have prior experience to build from. I will try to incorporate their current experiences with guided inquiry activities to deepen their understanding of forces. However, forces will only be a part of what we will be studying during this unit. Students will also be working to improve their questioning and exploring skills.

When designing the unit, I will plan to offer open-ended questions in which they have to figure out the best way to go about solving. Through this they will have to collaborate with their peers, rely on prior knowledge, and ask clarifying questions to begin exploring what forces are.

**Summary**

Through this project, I will be working to answer the question: *How might student achievement be supported through inquiry-based teaching?* In Chapter One I shared my prior experiences with inquiry in the classroom, both while in school and through teaching. I also outlined the importance of providing students with opportunities to think like a scientist as
opposed to just memorizing facts. Working to create and practice critical thinking skills are very powerful tools to have as one goes through life. Chapter Two consists of a literature review in which I share what work has been done already with respect to basing a curriculum around inquiry learning. I also outline what inquiry is and what it looks like in a classroom. From there I explore the advantages and typical challenges to using inquiry. Finally, I finish Chapter Two explaining the effectiveness of using the Understanding by Design framework to create effective lessons and units. In Chapter Three I outline what my curriculum design project will look like. This includes general information about my school and students as well as a timeline of the work I completed. Finally, in Chapter Four I explain and reflect on the work I have done for this curriculum design project.
Chapter Two

Literature Review

Introduction

Chapter One discussed the importance of students engaging in science inquiry experiences as opposed to just memorizing facts and figures. Because not everyone is interested in science, it is not realistic to push all students to become science experts. However, being critical thinkers is extremely important to becoming a well-rounded and active citizen. This has lead to the question: *How might student achievement be supported through inquiry-based teaching?*

The following chapter examines what is meant by inquiry-based instruction, as well as, how to effectively structure an inquiry unit to support students while allowing them the opportunity to be scientists. Following this, the different types of inquiry are discussed with an explanation of how they build on the previous type. Both teachers and students play an important role in an inquiry classroom, which is explored next. The strengths and challenges of utilizing an inquiry-based structure in a classroom are also discussed. Finally, the use of the Understanding by Design framework is examined for its effectiveness and is shown how it can be used to create effective and engaging lessons.

Inquiry In The Classroom

Using inquiry in the classroom involves students developing their own understanding and knowledge about a topic. This can take many forms be it problem-based learning, case method instruction, active learning, activity-based instruction, project-based learning, team-based learning, situated learning, anchored instruction, and discovery learning (Malone, 2008). Along with these different strategies, the students can assume
different levels of autonomy when participating in inquiry lessons. This all depends on what the students are ready for and what routines and structures the teacher has in place. The key to inquiry-based learning is that the learner is required to ask questions, find answers, and create links to previous learning and understanding, as opposed to memorizing facts and figures (Deskins, 2012). Bell, Smetana, and Ian (2005) expressed that in order for an activity to truly be inquiry-based, the students need to be answering a research question and using data as evidence to support their claims and conclusions.

Inquiry-based learning can take many different forms, but it all comes down to how the students are going about learning a topic. A well-planned inquiry lesson allows the students to question and search for their own answers. Kuhlthau, Maniotes, and Caspari (2007) stated that inquiry “…is an approach to learning whereby students find and use a variety of sources of information and ideas to increase their understanding of a problem, topic, or issue” (p. 2). They went on to explain that inquiry is not just knowing the answer. It is more about the process of getting to the answer. Teaching through inquiry engages and challenges students to connect what they are learning in class to what they experience in the world around them (Kuhlthau et al., 2007). Similarly, the National Science Teachers Association (NSTA, 2004) defined science inquiry as

... a powerful way of understanding science content. Students learn how to ask questions and use evidence to answer them. In the process of learning the strategies of scientific inquiry, students learn to conduct an investigation and collect evidence from a variety of sources, develop an explanation from the data, and communicate and defend their conclusions. (p. 1)
These definitions highlight the investigative nature of this type of learning. Students use this inquiry to pull in their previous knowledge and experiences to build questions to explore. This allows students to make connections across disciplines and bring their knowledge together as opposed to just memorizing facts and figures. They learn to ask questions and search out answers. This may take the form of looking something up in a book or online, to doing an experiment, to even asking the teacher. In these situations, the teacher is a valuable resource to the students. Instead of the teacher always telling the students when they will be learning about a specific topic, such as cell division or the force of gravity, students will ask the teacher to help explain these topics when they find that they need the information.

Students asking questions and investigating topics lend themselves to being a social type of learning. Kuhlthau et al. (2007) went on to state “Although [inquiry] is often thought of as an individual pursuit, it is enhanced by involvement with a community of learners, each community learning from the other in social interaction” (p. 2). Here, Kulthau et al. (2007) highlighted the benefits of working on solving a problem in a group. This community can be as small as the student working with a fellow student or the teacher, or as large as the whole class, their school, or even the community. Students can and should use the resources available to them to help investigate the problem at hand. This benefits the learners in ways beyond just helping them answer their question. It helps them learn how to work in groups, find outside experts, and utilize the resources they have on hand. Through learning in this way, as opposed to a traditional lecture based class, the learners are becoming self sufficient in learning how to go about answering questions (Walker & Leary, 2009; Zion & Mendelovici, 2012). They obviously may still need to find
outside resources and people to help answer their question, but they are learning how to go about finding these resources and using them to their full potential. This is one of the strengths of inquiry-based lessons. Students are learning how to problem solve while they learn the topics and concepts.

**The Structure For Inquiry-Based Learning**

As described in the previous section, inquiry requires students to be asking questions and searching for their own understandings and answers. These investigations do not always end with a clear-cut answer or solution. They focus more on the process that was used to get to those solutions and understandings. Kuhlthau et al. (2007) suggested that using inquiry gets students to go past finding the correct answer and causes them to make connections between what they are learning and their everyday lives or other content areas.

Many models have been created to facilitate inquiry opportunities in a classroom. One model is the Biological Sciences Curriculum Study 5Es. In this model, the 5Es stand for: Engaging Learners, Exploring Phenomena, Explaining Phenomena, Elaborating Scientific Concepts and Abilities, and Evaluating Learners (Bybee, 2014). Building off of the 5Es is the 7E Structure that is comprised of seven stages: Elicit, Engage, Explore, Explain, Elaborate, Evaluate, and Extend (Miranda & Hermann, 2012). A third model is the Stripling Model that has a similar list of six components: Connect, Wonder, Investigate, Construct, Express and Reflect (Deskins, 2012). All of these models, as well as most other inquiry-based models, have four commonalities among them: Engage, Explore, Explain, and Extend (Marshall & Horton, 2011).
Engage. In the first step of these models the students need to become Engaged in what they are learning. This is where the hook of the lesson is used to get the students to start wondering why or how about a question or problem. In this stage teachers need to build students excitement and curiosity around the given topic. During this time teachers are also able to identify misconceptions and prior knowledge that the students may have (Marshall & Horton, 2011). While the teacher works to engage the students in the planned learning, it should be clear to the students what the intended learning targets and goals are as they work to make connections to their prior knowledge (Bybee, 2014).

Explore. Moving on to the Explore stage, students need to be provided with opportunities to investigate the questions that arose during the engage step. Bybee (2014) stated, “The exploration lesson or lessons provide concrete, hands-on experiences where students express their current conceptions and demonstrate their abilities as they try to clarify puzzling elements of the engage phase” (p. 11). This involves the teacher preparing activities and experiences for the students to investigate phenomena, observe patterns, and formulate explanations. During this time misconceptions need to be addressed. The teacher needs to identify and provide opportunities for students to explore phenomenon around these misconceptions to build a stronger understanding of the concept. While working in the explore phase, students may “…generate new ideas, explore questions and possibilities, and execute a preliminary investigation” (Piyayodilokchai, Panjaburee, Laosinchai, Kepichainqrong, & Ruenwongsa, 2013, p. 147).

Explain. In the third step, Explain, students work to use what they learned while they explored to explain the concept being learned. In this stage students work closely with the instructor to help focus what they saw and learned in the engage and explore stages
towards the intended learning goals (Piyayodilokchai et al., 2013). In addition, this is when “… prior knowledge is united with learning from the current investigation in an effort to resolve disequilibrium and generate conceptual understanding” (Marshall & Horton, 2011, p. 94). These student explanations can take many forms from oral, written, drawings, to presentations. It is important to allow students to express their learning in different ways in order to challenge and extend their ability.

**Extend.** Finally, students are expected to Extend, and as a result deepen, their new knowledge by applying it to a new situation (Marshall & Horton, 2011). “The intention is to facilitate the transfer of concepts and abilities to related but new situations. A key point for this phase – use activities that are a challenge but achievable by the students” (Bybee, 2014, p. 11). By having the students apply their learning, they are able to make connections to previous learning as well as explore how this new knowledge connects to the world around them.

**Types Of Inquiry**

Inquiry lessons can take a variety of approaches. A major component to the different forms of inquiry is related to the level of autonomy the students are given. Bunterm et al. (2014) explained that there are four levels to inquiry depending on how autonomous the teacher intends the students to be. In order of increasing autonomy, these four levels are called confirmatory inquiry, structured inquiry, guided inquiry, and open inquiry. In this section, these four levels of inquiry are described as well as how they are used to build off of each other.

**Confirmatory inquiry.** Confirmatory inquiry utilizes the least amount of student autonomy. In this level, the students are already presented with the question, procedure,
and the results before they partake in the activity (Bell et al., 2005). They will be working through the activity, analyzing their own data, and comparing their results to what was already learned. This requires the least amount of student autonomy as the teacher has provided a lot of the information to the students already. They are mostly focusing on doing the activity and analyzing their data.

**Structured inquiry.** Structured inquiry provides slightly more autonomy for the students. The main difference between a confirmation and a structured inquiry activity is the timing of the activity. As opposed to being done after the concept is taught, as with confirmation inquiry, structured inquiry is done to teach the new concept. In this situation, a research question is still posed by the teacher and a procedure is provided. The difference is that the results are not yet known (Bell et al. 2005). In structured inquiry, “Students are involved through hands-on investigations in the process of science and develop basic inquiry skills, such as making observations, raising hypotheses, collecting and organizing data, drawing conclusions, making inferences and finding solutions” (Zion & Mendelovici, 2012, p. 384). This stage allows students to build and develop their inquiry skills through practice with drawing conclusions from their data.

**Guided inquiry.** Guided inquiry allows students more autonomy to determine how to go about solving a teacher’s provided question. At this level, students are provided a guiding question but must work together to determine how they would go about solving it. This includes coming up with a procedure for their investigation. “Students typically get very little practice in designing their own investigations: therefore, guided inquiries have the potential to take student engagement and ownership of the lab to a new level” (Bell et al., 2005, p. 32).
**Open inquiry.** Open inquiry affords the greatest amount of student autonomy. At this level students identify and develop their own question, methods, and analyze their own data. Teachers can help define the scope of the project to help lead to general outcomes but ultimately the student is in charge of determining their specific research question. Open inquiry does not take the teacher out of the picture all together. They are to be used as a resource to help facilitate and guide the students through the process. At this level, students are focusing on developing a research question in which to investigate. This level of inquiry also provides the greatest amount of student ownership as they are continuously engaged in decision making throughout the entire process (Zion & Mendelovici, 2012).

**Synthesis.** Each of the four stages is just as important as the last. Bell et al. (2005) stated:

> Although the goal is to help students develop the skills and knowledge to conduct Level 4 inquiries [open inquiry], they cannot be expected to begin there. Students need practice in inquiry, building up to increasingly open and complex levels. Students will reap as little benefit from being thrown unprepared into Level 4 inquiry activities as they will from being held at low-level activities. (p. 33)

Students need to learn how to do this process one step at a time. They need to be guided into the more complex concepts of actually designing their own experiment or coming up with their own guiding question. That being said, studies have shown that students taught using guided inquiry show greater improvements in science content and science-processing skills compared to those where were taught using structured inquiry (Bunterm
et al. 2014; Sadeh and Zion, 2009). Keeping these ideas in mind it is important to put into place the scaffolding to prepare the students to succeed in the later stages of inquiry.

A Teacher’s Role In Inquiry

In order for students to be able to continually ask questions and work to dig deeper, teachers must be ready fill a variety of roles during any given lesson. Teachers need to understand that they are not just teaching specific content when they use inquiry. Some descriptions of the teacher’s role in inquiry are over simplified. Fradd and Lee (1999) described teachers who want to use inquiry need to be facilitators. But, as Crawford (2000) expressed, in order to teach inquiry effectively, a teacher must realize that they will be doing more than just facilitating students answer questions.

When teaching through inquiry, the teacher is not simply passing information onto the student or facilitating a discussion or activity. Although they may take on these roles at different points, they are working with the student to help and guide them to the information. Through a study exploring experienced teachers who use inquiry effectively in their classroom, Crawford (2000) determined 10 key roles a teacher must take on in order to be an effective inquiry teacher. Her list is as follows:

- Motivator;
- Diagnostician;
- Guide;
- Innovator;
- Experimenter;
- Researcher;
- Modeler;
• Mentor;
• Collaborator; and
• Learner (pp. 931-932)

Some of these roles are essential while in the classroom working with the students. Being a motivator to keep the students working is very important, especially when an experiment may not go the way they wanted. Students may find it easier to give up as opposed to working through to find what went wrong or why the results are the way they are. Another example is being the modeler. This involves demonstrating to the students what it is like to be a scientist. What types of questions do they think at different parts of a project? What questions do they ask when they get a surprising result? By modeling these behaviors, the students can see some concrete examples to try to replicate in their own learning (Topping & Trickey, 2014).

Other roles Crawford (2000) listed may not be directly related to the time the teacher is working with the students in the classroom. Instead these are roles the teacher takes on in order to be prepared for and create effective inquiry lessons. “The role of researcher involves the teacher evaluating his or her own teaching and engaging in solving problems” (Crawford, 2000, p. 932). Here the teacher is taking and analyzing student data to determine if they are being effective at reaching the intended learning goals. Similarly, the teacher needs to take on the role of innovator. They need to use and sometimes come up with new ideas that can be used in the classroom to create engaging and effective inquiry lessons.

Providing opportunities for students to struggle with material and learn from their mistakes or bad data is an important part of the learning process (Swartz, 1976). Students
are able to learn from their mistakes as well as experience what it is like to explore a real world topic. One does not always get clear results that make sense. Sometimes, they will need to go back and try again. In order to facilitate this type of learning the culture of the class needs to be established in such a way that mistakes and failure are recognized as part of the learning process and allowed in class. The role of creating this class culture lands on the teacher. They need to be able to establish norms within the classroom and connect with their students so that they will feel comfortable to open up and be wrong at times. Creating opportunities for students to struggle with concepts is an important part of the teachers planning. By knowing what background knowledge their students have and where they are developmentally, teachers can design lessons that will push them to ask and explore challenging questions (Zion & Mendelovici, 2012). If the tasks are too difficult then the students can become stuck in failure. With careful planning, the activities can be developed to create a challenge the students will struggle with but ultimately will lead to success.

Teachers need to help prepare their students for success by providing them with the tools they need. Students need to learn how to ask questions, dig deeper into a concept, and analyze data, among other things (Harlen, 2013). It then becomes the teacher’s role to model these behaviors to their students. This is also a time when direct instruction may be needed. This direct instruction can be in the form of showing the students explicit examples of questions to ask in order to keep going, how to take notes about their procedures and observations, or how to analyze data to make conclusions from their experiment. Kuhn and McDermott (2017) gave suggestions for helping students direct their questions in the following list:

• Establish the “Big Idea” for the activity/Unit
• Questions must fit the Big Idea
• Questions must be testable
• Questions must be safe to perform at school and done with available resources.

(p. 83)

This goes back to the different types of inquiry in which a framework needs to be in place for the students to build from. They need to learn how to participate in inquiry incrementally before they can be expected to participate in open inquiry (Zion & Mendelovici, 2012).

One shift a teacher needs to be aware of when transitioning to an inquiry-based curriculum from a more traditional setting is that they may not get through as much content as they once did. Instead of covering a large breadth of content, the students will be digging deeper into key concepts and learning how to ask questions, design an investigation, analyze data, and develop conclusions based on evidence (Bell et al., 2005; Maguire, Myerowitz, & Sampson, 2010; NRC, 1996). In many cases this will be a switch for the students as well. Because of this, the teacher needs to be ready to continually question the students, motivate them to keep going, and model good inquiry behavior to support their students as they work through this style of learning.

A Student’s Role In Inquiry

A main component of inquiry learning is that the student is building their own understanding of a concept through analyzing data and discussing with their peers. Because of this, inquiry-based learning is very student centered (Deskins, 2012). As discussed in the previous section, it is important for the teacher to come up with guiding questions and to design activates to assist the students through this learning experience,
but it requires the students to work through being problem solvers. The student’s role will change over time as they gain more tools and skills around inquiry (Bell et al., 2005). An example of this is when the students become more comfortable asking questions, they will be able to rely on their peers as opposed to needing the teacher to ask questions to keep the activity moving. Due to this, at the beginning, students will be relying on teachers to model and guide their work as they learn these new skills.

The students need to be all right with the feeling of not knowing the answer. Many students struggle with this concept as they have always learned from the teacher telling them the information. This is not to say that they need to be comfortable with it but that they realize that with time they will learn the information (Marshall & Horton, 2011). Students need to be placed slightly outside of their comfort zone in order to continue to grow. This is the same idea as Vygotsky’s (1978) zone of proximal development in which students are stretched just past their current knowledge to understand a new concept. It may be the teacher’s responsibility to find this zone where students are challenged but not overwhelmed, but the students’ role is to continue to persevere in the face of this challenge.

In order to learn new information, students rely on making connections to what they already know. When presented with something new, the students will rely on their previous knowledge and experiences to make sense of it. This is where the collaborative nature of inquiry is so important. Giving the students opportunities to discuss and explain what they are observing with their peers allows them time to learn from each other’s experiences. In a constructivists view, new understandings are built from current understandings of concepts (Osborne & Dillon, 2010; Fensham, Gunstone, & White, 1994).
Through collaboration with their peers, their collective prior knowledge allows them to work together to build an understanding of the new concept they are working on.

The students need to be engaged in the work they are doing. This takes careful planning from the teacher but can allow the students to take charge of their learning. Wilcox, Kruse, and Clough (2015) stated, “The distinction between teaching science merely through hands-on activities and teaching science through inquiry is the degree to which students must mentally engage” (p. 64). This includes giving the students opportunities to make decisions and explore their misconceptions. As the students become better at the inquiry process they will be able to use the tools provided to them to ask good questions and collaborate with their peers in order to investigate guiding questions posed to them.

**Strengths And Advantages Of Using Inquiry In The Classroom**

The use of inquiry-based instruction benefits the students in a variety of ways. By providing the students with opportunities to explore and investigate they are being prepared for future situations when they must find an answer themselves. There are numerous strengths to inquiry-based learning. These strengths include; increased learning through collaboration and understanding of how science is performed (Duren & Cherringon, 1992; Manion & Alexander, 1997; OECD, 1999), creating a deeper understanding of the concepts that lasts over time (Harlen 2013; Patrick & Yoon, 2004; Todd & O’Brien, 2016), closing the achievement gap between groups of students (Laursen, Hassi, Kogan, & Weston, 2014), and, building critical thinking skills in all (OECD, 1999; Yager & Akcay, 2010).

One strength of inquiry-based learning is increased student achievement. Yager and Akcay (2010) conducted a study around inquiry in middle school science classrooms. In
this study, they analyzed topics like student achievement around concepts, application of new knowledge, and student attitude towards an inquiry-based science class in comparison to a traditional class. Through their findings all of the categories examined showed either no difference or an improvement through using inquiry as opposed to a traditional lesson.

According to Yager and Akcay (2010), some of the topics that showed significant improvement through inquiry, as compared with traditional teaching, were:

- Increased ability to apply concepts to new ideas;
- Increased creativity;
- Increased ability to use science process skills;
- Increased understanding of the nature of science; and
- Increased attitude towards science inquiry (pp. 7-10)

It can be noted that none of these are concept specific. In a traditionally taught class a student can learn all of the concepts but may not know how to actually do or apply the science. Through the use of inquiry, students are learning how to make connections to prior knowledge and explore by becoming critical thinkers, much like scientists.

Another strength of learning through inquiry is that students do not learn alone. They are working with their peers to build their understandings. Teaching through inquiry relies on students collaborating with each other. According to the Organization for Economic Co-Operation and Development (OECD) students must use each other’s collective prior knowledge to create new understandings for the concepts being learned (OECD, 1999). Manion and Alexander (1997) conducted a study in which students worked through tasks collaboratively. While they worked, they were directed to explicitly discuss their thinking with each other. They found that through having students with a variety of
abilities working together, all students improved their metacognitive thinking ability. Not only are these students able to create better understandings of the concepts through this collaboration, but it has been shown that learning through collaboration maintained knowledge over extended periods of time (Duren & Cherringon, 1992).

This maintaining knowledge over time is also attributed to students digging deeper into content. Using inquiry has proven to develop substantial understanding of concepts through the students investigating the concepts and ideas as opposed to being told through lecture (Harlen 2013; Patrick & Yoon, 2004; Todd & O’Brien, 2016). Because of this, in an inquiry-based classroom, it may seem that less science content is covered. But instead, the students are learning how to conduct an experiment, ask questions, and determine the validity of an argument, among other things (Marshall & Horton, 2011). These extra steps do take more time but allow the students to build their own understanding in their own way.

Not only does inquiry help students create a deeper understanding of the material but it also provides a more equitable learning environment for all students. Laursen et al. (2014) conducted a study in which they investigated the effects of implementing inquiry-based instruction in college mathematics classes. They found that all students benefited from this type of instruction but that the gender gap between men and women in mathematics is significantly reduced through this type of learning. As one student reported “... math is ‘not just one way only’” (Laursen et al., 2014, p. 415). This gets back to a central tenet of inquiry in that everyone learns and discovers in their own way. If students are provided with the support to create their own understandings of concepts they will make more sense to them.
Lastly, learning through inquiry can help build critical thinking skills. It is not possible for students to learn everything they need to know during their time in school. Because of this, it is extremely important that the students develop critical thinking skills in order to be successful as future learners (OECD, 1999). The OECD went on to say that inquiry-based teaching allows students opportunities to explore, ask questions, and build the skills needed to continue to ask challenging questions and become lifelong learners.

**Challenges Of Using Inquiry In The Classroom**

The transition from a more traditional classroom to an inquiry-based classroom is where most teachers find the most challenge in teaching through inquiry. Some of these challenges include overemphasizing content instead of the inquiry process, the time commitment necessary to learn through inquiry, teacher preparedness, and student frustration as the change is made (Bunterm et al., 2014; Gutierez, 2015). Many of these challenges stem from teachers lacking the necessary preparation and training to effectively use inquiry in their classroom.

In a study conducted by Furtak (2005) different teachers shared their experiences with holding back answers for the sake of students searching to find their own understanding. The different teachers used a variety of approaches to assist their students while holding back answers. One conclusion that was determined was that teachers with more experience or training in teaching through inquiry do better assisting the students’ find their own explanation. Because of this, teachers who are new to inquiry might struggle with holding back answers. This can affect the inquiry process as students can learn to go to their teacher for solutions.
Students may resist the change from a traditional class to an inquiry-based one. When students are familiar with the traditional note taking, studying, taking a test format, being pushed to something new can be a challenge. This can especially be hard when they are expected to solve problems that are new to them, struggle to use prior knowledge to explain new observations, and to be all right with being wrong at times (Sadeh & Zion, 2009). This goes back to the many different roles that Crawford (2000) described a teacher must take on in order for inquiry to be successful. On top of these roles, Zion and Mendelovici (2012) explained that teacher confidence is an important aspect of inquiry-based learning due to the teacher’s integral role in the process. This confidence will take time to develop and most likely will not occur if the lessons are not carefully developed.

Some opponents of inquiry claim that a class is not able to cover as much content as it takes longer to complete inquiry lessons which will set them behind (Holliday, 2000). This statement may be true in the sense of actually knowing different scientific laws and theories. But, the strength of inquiry comes when the students learn how to explore a question and create their own evidence-based explanation for the world around them. When learning through inquiry the process is just as important as the end product (Markham, 2013). This emphasis on the process of developing an understanding as opposed to just memorizing the concept is central to teaching through inquiry. It is true that this process may take more time but the end result is that students are able to be critical thinkers and learn how to explore the world around them as opposed to just knowing facts and figures (Nybo & May, 2015).

As shown in the previous sections, teaching through inquiry has many benefits for the students. This suggests that even with these challenges it is beneficial to transition from
a traditionally taught class to an inquiry-based one. For this to be the most effective the proper supports need to be provided for both the students and the teachers.

**The Understanding by Design Framework**

Careful planning is necessary to create effective lessons. The Understanding by Design (UbD) framework created by Wiggins and McTighe (2005) provides a structure to assist in creating effective lessons to teach. The following section explores why the UbD framework was chosen and how the framework can be implemented.

Traditional course development typically follows a linear progression in which the lessons are created and delivered and then the assessment is determined based on the perception of the instructor. This has been found to not be the most effective way to create a curriculum (Minbiole, 2016). On the other hand, in the UbD framework the essential questions and goals for the unit are identified before any lessons are designed. Then, the assessments are created to align with these goals and essential questions. Finally, the individual lessons and activities are created to ensure that the desired learning occurs (Wiggins & McTighe, 2005). Due to this sequence of planning, UbD is considered to be a backwards design process for creating curriculum. Several studies have shown improvement in student achievement through the use of backwards design processes and specifically UbD (Childre, Sands, & Pope, 2009; Emory, 2014; Kelting-Gibson, 2005; Minbiole, 2016; Noble, 2011).

Backwards design curriculum creation focuses on the goals and essential questions the teacher wants the students to know at the end of the learning process. Childre et al. (2009) made a distinction between student knowledge and student understanding in that many students are able to memorize facts but that does not mean that they truly
understand the material. Through the use of essential questions and big picture goals, along with intentional scaffolding to support their students, Childre et al. (2009) found that all of their students, no matter their ability or disability, showed an improvement in performance. They attributed this to many things including the ability to make the learning more relevant and meaningful as the students work towards answering the essential questions through their own processes and discussions.

**Implementing Understanding by Design.** When using UbD the first step is to determine the intended outcomes. This is an important first step, as one needs to determine where they will be heading before they start teaching. As stated in *Understanding by Design (Wiggins & McTighe, 2005)*, some important questions to answer during this first phase of the development are:

- What established goals/standards are targeted?
- What essential questions will be considered?
- What understandings are desired?
- What key knowledge and skills will students acquire as a result of this unit? (p. 328)

These questions will undoubtedly lead to more but they are the key questions that need to be thoroughly answered in order to determine what it is exactly the teacher wants the students to learn during the unit.

The next step in UbD is to determine what evidence will show the understanding defined in the first step. How will the teacher know that the students have learned the material? This step involves determining what assessment tools and strategies will be used to gauge understanding (Wiggins & McTighe, 2005). What do the students need to be able
to do in order to show that they can answer the essential questions determined in part one?

Working through this part requires aligning specific questions to be posed to the students in order to determine understanding. There are many ways in which students can show their understanding, as opposed to only using a standard test question. Coming up with ways in which a variety of learners can demonstrate understanding will be key for this part of the process (Wiggins & McTighe, 2005). This part of the design process requires careful work to make sure that any sort of assessment used or created aligns well with the intended learning for the students.

The final step in UbD is to plan out the actual learning that will occur. This planned learning is now driven by the previous two steps, which have already been carefully designed. A key question to consider in this part of the design is “What learning activities and teaching promote understanding, knowledge, skill, student interest, and excellence?” (Wiggins & McTighe, 2005, p. 193). Working through this question will start to lead to effective lessons for the intended outcomes. But, only planning for the outcomes will only get one so far. The teacher needs to make the lesson engaging for all of the learners.

Wiggins and McTighe (2005) stated that a “good” plan must be both engaging and effective. They went on to elaborate on these two terms by saying “By engaging, we mean a design that the (diverse) learners find truly thought provoking, fascinating, energizing. ... By effective, we mean that the learning design helps learners become more competent and productive at worthy work” (Wiggins & McTighe, 2005, p. 195). This entails more than just having the students enjoy the work, although that can be helpful for engagement. The
students need to be engaged in the content, making sure to be making connections to real world applications.

To help with making engaging and effective lessons, Wiggins and McTighe (2005) provide the instructional planning acronym WHERE TO, which stands for:

**W**-Ensure that students understand WHERE the unit is headed, and WHY.

**H**-HOOK students in the beginning and HOLD their attention throughout.

**E**-EQUIP students with necessary experiences, tools, knowledge, and know-how to meet performance goals.

**R**-Provide students with numerous opportunities to RETHINK big ideas, REFLECT on progress, and REVISE their work.

**E**-Build in opportunities for students to EVALUATE progress and self-assess.

**T**-Be TAILORED to reflect individual talents, interests, styles, and needs.

**O**-Be ORGANIZED to optimize deep understanding as opposed to superficial coverage. (pp. 197-198)

Wiggins and McTighe (1998) have created an Understanding by Design Unit Template to start unit planning. This template helps a teacher go through the backwards design process while making sure to consider all aspects of the three parts; Identify Desired Results (Stage 1), Assessment Evidence (Stage 2), Learning Plan (Stage 3).

Utilizing this guide for lesson planning will assist in creating learning experiences that will be tailored to specific students while providing them opportunities to explore and learn in an exciting environment.
Summary

In this chapter, a review of current literature was conducted around the use and implementation of an inquiry-based curriculum in a science class. The review showed that using inquiry creates opportunities for students to collaborate with their peers and experience exploring topics of our natural world, much like scientists do. Creating these opportunities not only give them the tools to explore their own questions but also helps them build deep long lasting knowledge of concepts by creating their own understanding. The framework of inquiry can vary slightly depending on what model is used but they all have the basic components of Engage, Explore, Explain, and Extend.

The use of support is integral in the implementation of inquiry. Students cannot be expected to participate in open inquiry from the start. Scaffolding needs to be built by starting with the use of confirmatory and structured inquiry before moving on to guided and open. During this time, important tools for the students need to be modeled and developed. While the students are developing these tools and strategies the teacher must take on many different roles to help support the students.

Teaching through inquiry provides many opportunities for students. They are provided with opportunities to dig deeper into concepts and ideas to build their own explanations and understandings. Working closely with their peers they are able to learn from each other and practice conveying their current knowledge and understanding to others. As well, all of this learning is shown to last longer due to the fact that the students took part in their learning and constructed their own understanding as opposed to just being told. All of the skills students learn through participating in inquiry-based lessons provide them with a toolkit to go out into the world and explore more questions.
Implementing inquiry in a classroom will not happen without its challenges. Through careful planning on the teacher’s part and the use of proper scaffolding, students can adapt and learn how to be successful in this new and beneficial learning environment.

Creating effective lessons does not happen by accident. Careful designing and planning are necessary in order to help all students learn. Using the Understanding by Design framework provides a proven method in which to create effective lessons that focus on overarching questions and goals for the students.

Chapter Three outlines the intended curriculum design project including how the Understanding by Design framework was used. The setting and intended student participants are described. Following this, an explanation of the project timeline is shared showing the sequence in which the project was developed.
Chapter Three

Project Description

Introduction

The previous chapter’s literature review provided a background of what inquiry in the science classroom looks like. This chapter starts by describing the project and what the curriculum development will look like. Following this, an explanation is given for how the unit plan will be shared in a binder for others to use. Next, the setting and participants for whom the curriculum is intended is explained. Afterwards, an outline on how the Understanding by Design framework will be used to help design the unit. Lastly, the timeline for the development, implementation, and assessment of the new curriculum is described. This whole unit curriculum design process is guided by the exploratory question of: How might student achievement be supported through inquiry-based teaching?

Project Description

As noted in the previous chapter’s literature review, utilizing an inquiry-based curriculum in a science class can lead to a better and longer lasting understanding of topics and concepts. For this project, a new unit for utilization in a ninth-grade science classroom was designed. It introduces forces, specifically how Newton’s Laws impact objects in the world around us.

The entire unit has been constructed from the overarching guiding questions, to the day-to-day lessons and activities. The curriculum was created to meet the current Minnesota state science standards as well as the Next Generation Science Standards (NGSS), which the state of Minnesota will most likely adopt in the coming years. Specifically, the standards addressed are:
• HS-PS2-1. Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration; and

• HS-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision (NGSS Lead States, 2013, p. 84)

• Formulate a testable hypothesis, design and conduct an experiment to test the hypothesis, analyze the data, consider alternative explanations, and draw conclusions supported by evidence from the investigation;

• Develop possible solutions to an engineering problem and evaluate them using conceptual, physical and mathematical models to determine the extent to which the solutions meet the design specifications;

• Communicate, justify, and defend the procedures and results of a scientific inquiry or engineering design project using verbal, graphic, quantitative, virtual, or written means;

• Recognize that inertia is the property of an object that causes it to resist changes in motion;

• Explain and calculate the acceleration of an object subjected to a set of forces in one dimension (F=ma); and

• Demonstrate that whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted by the second object back on the first object (MN Dept. of Education, 2010, pp. 27-33).
Due to the fact that the current forces unit is structured to teach the information and then experience it in a lab, this new inquiry-based unit was completely designed from the ground up. As seen in the literature review, the “teach and then lab experience” does not lead to lasting understanding of a topic. By approaching the creation of this unit from a clean slate provided the opportunity to determine the sequence and activities that best suits deeper and longer lasting understanding of the topic. To help with the design of the unit, the Understanding by Design framework was implemented. Before the unit design plan is explained, the physical layout of the unit curriculum is described, along with the setting and population the curriculum is intended for.

**Method**

The culminated unit plan is presented as a physical and digital binder with all of the resources organized together (Appendices A-D). Organizing the resources together in this way allows for easy opportunities to share the unit with others. The binder starts with a description of the unit to help teachers understand the basics of the unit. This is presented in the form of a completed Understanding by Design Unit Template (Appendix A) giving details to the three steps, identifying desired results, assessment evidence, and learning plan, from the UbD framework (Wiggins and McTighe, 2005). The binder then contains a section for the assessments developed (Appendix B). This section comes near the beginning because when using a backwards design framework, the assessments need to be determined before the learning activities. Next, there is a calendar outlining the unit progression (Appendix C). This is comprised of the essential questions and major activities that will be conducted each day. Following this is a more detailed teacher’s plan that outlines the sequence and daily activities throughout the unit (Appendix C). The last
section of the binder includes each of the activities and worksheets that the students will use (Appendix D).

**Setting**

This curriculum was designed for a Midwest suburban high school, grades nine through twelve. The school’s population of about 1,200 students has a rough demographic breakdown as follows: 87% Caucasian, 3% Black, 3% Asian, 4% Hispanic, and 3% Two or More Races. In addition to this, there are about 9% of students in the free and reduced lunch program and 8% of students have Individual Education Programs (IEPs) or 504 plans. The school has a six-period day and students are in each class for about 50-55 minutes.

**Population/Participants**

The specific class this curriculum was designed for is a ninth-grade general science class. This is a required class in this high school’s program, and all students must pass it. The course is designed to be an introduction to science in high school. The broad subjects covered in the course are chemistry, physics, and engineering. Some of the topics discussed within these subjects are atomic history and structure, compounds, chemical reactions, energy, waves, forces, motion, and the engineering design process. Because all students are required to take this course, a wide spectrum of interests and ability levels in science will be present. This is a main reason for picking this particular class for this project, as it is focusing on providing all students the opportunity to understand science, not just those who enjoy it.

Since all students take this class, there are ten sections of the class resulting in a variety of instructors teaching it. When completed, this unit curriculum will be shared with
all ninth-grade science teachers in hopes that all students will have an opportunity to experience inquiry during the force unit.

**Timeline**

To help facilitate the creation of this unit curriculum, a timeline was created of what was completed using the Understanding by Design framework. To start the process, the overarching questions and goals for the students to be able to answer and do by the end of the unit were identified. This included aligning them with the state and NGSS science standards addressed earlier. With these goals determined, common misconceptions high school students have about forces were explored to make sure they are addressed during the learning process (Appendix A). Finally, what knowledge the students will know, and what skills the students will be able to perform by the end of the unit were determined.

With these goals outlined, the next step was to determine how student learning would be assessed. Using the overarching goals of the unit, assessments were created that will show varying levels of mastery of the given content. During this part of the design process, it was important to keep diverse learning styles in mind. Different ways for students to demonstrate their mastery of the information needed to be considered. While planning the assessments, both formative and summative assessments were created. The formative assessments allow teachers to continually improve their lesson plans as they work through the unit if there are misconceptions or misunderstandings that arise. The summative assessments provide teachers with evidence that demonstrates that students have met the intended outcomes. The summative assessments are found in Appendix B while the formative assessments are in the lesson plans and teacher notes in Appendix C.
Each of the assessments created were checked for how the questions related back to the overarching goals of the unit. This included determining what role the assessment played in achieving the goal. Whether it is for gauging prior knowledge, evaluating what has or has not been learned so far, or assessing for mastery. It was also decided what products or performances the students would need to complete in order to show their current understanding at different points and eventual mastery of the material.

Finally, using the assessments as guides, the learning activities that students will participate in were determined. Once it was established what the students need to know, it was possible to explore different ways students can learn these concepts and ideas. This started by researching what other teachers have already done and created around these particular topics. Using these ideas as a starting place, inquiry activities were created in which the students will be working to build their own understandings of the concepts. When creating these lessons, it was important to evaluate them all using the WHERETO acronym (Wiggins and McTighe, 2007, pp. 197-198), as discussed in Chapter Two. Using this in the design of the lessons ensured they all had the important components to make the lesson both engaging and effective.

In order to provide the appropriate scaffolding for the students to be successful using inquiry, the unit starts out using structured inquiry and moved towards guided inquiry. Because only a single unit was designed, it would not be realistic to expect the students to be experts in inquiry by the end. This will take time and more support throughout the school year.
To assist in creating this unit, the Understanding by Design Unit Template (Wiggins and McTighe, 1998) was utilized. The completed template for this unit is shown in Appendix A.

**Assessment Of Curriculum Effectiveness**

In order to determine the effectiveness of the designed curriculum, two main methods of student assessment will be used. First, student understanding of concepts and ideas around forces will be compared to previous year’s data. The students are not being asked the exact same questions but there are similar topics being covered in the assessments to give the instructors indicators for comparison. Another assessment tool that will be used is the Force Concepts Inventory (Hestenes, Wells, & Swackhamer, 1992). This multiple-choice test focuses on the conceptual understandings of Newton's laws and forces. Having the students complete this test will provide needed data to show if students are understanding forces on a conceptual level or not. This test will also provide an opportunity to build common data for coming years, allowing for better comparisons from year to year.

**Summary**

In Chapter Three, an outline of the curriculum design project was explained including standards that intend to be met. A description of how the project is going to be put together in a way that will facilitate its ability to be shared and used by others was expressed. The setting and students that the unit will be created for was outlined. Next, how the Understanding by Design framework was used in order to help develop effective lesson plans that will keep the students engaged in the lessons and working towards the intended outcomes was reported. Finally, an outline of the timeline followed in order to
complete the project was shared along with an assessment plan to determine the unit’s effectiveness. In Chapter Four, the outcomes and reflections about the curriculum design process are shared.
Chapter Four

Reflection

Introduction

Through the creation of this curriculum many important concepts and elements about inquiry, unit planning, and using the Understanding by Design framework were learned. These same concepts and elements about inquiry can help answer the question: How might student achievement be supported through inquiry-based teaching? This chapter examines important ideas and concepts that were learned while creating the unit curriculum. Next, key components and characteristics of the curriculum are described along with how it will be implemented and shared. Limitations to the curriculum are also addressed. Finally, implications of the project and possible future work are identified.

Creating The Curriculum

While creating the new curriculum, several findings in the literature review were found to be especially helpful. These findings include: understanding what inquiry is and the key components of it, the different types of inquiry and how they relate to each other, and how the Understanding by Design (Wiggins & McTighe, 2005) framework can be used to create effective and engaging lessons.

In the literature review it was found that all types of inquiry contain four main components: Engage, Explore, Explain, and Extend (Marshall & Horton, 2011). These four components form the basis for how the unit and specifically lessons within the unit were created. The unit and individual lessons within the unit begin with something engaging. This could be a question posed to get the students started thinking, such as “How can an egg be dropped and not break?” or “Why do objects fall to the ground?” Activities are also
used to stimulate student engagement. An example of this is the lead off activity in which the students play a variation of broomball in which they use brooms to push a bowling ball through a course (Appendix C). This activity engages the students through competition and physical movement while allowing them to experience and observe forces.

During the Explore stage is where learning through inquiry differs from a more traditional class in which students are told how phenomenon or concept works. In this unit, students partake in several activities in which they need to take data and make observations. Using this data, the class works collaboratively to make sense of what they observed and determine a common understanding of what they just experienced. An example of this is during the Force Activity 1 (Appendix D) in which the students experience and make observations of four different situations that demonstrate Newton’s First Law. While participating in the activity, the students have not explicitly been told Newton’s First Law. The activity is designed to allow them to explore situations that demonstrate this law of motion and for them to start making connections. This is a structured form of inquiry but it allows the students to experience a concept and start to use their own observations and data to explain what is happening.

The Explain stage was the hardest to plan for as a teacher. As inquiry is intended for students to work collaboratively to build their own understanding of the given concepts, it is important for the teacher to be there as a guide and not as an all-knowing source of information. This stage of the learning requires that adequate scaffolding be provided, allowing students to see the desired concept, as well as, opportunities for them to discuss and make connections to the information with their peers. During each activity, there are questions for the students to start pondering about what they experienced and how it
could be explained based on what they already know. Following each activity, the students are given opportunities to discuss what they observed and their current explanation for it as a group. This concept of having the students explain what they observe is different from a traditional class in which the students may observe something but then the teacher explains how it works. It is evident that this is a key component of inquiry as it is where the students are building their understanding of the concepts, but more importantly, they are learning how to use data and evidence to create an explanation. It became noticeable during the literature review and while creating the curriculum that this stage is where many teachers may struggle with using inquiry (Marshall & Horton, 2011; Piyayodilokchai et al., 2013). Because of this, teachers who plan to implement inquiry can benefit from learning from experienced teachers who use inquiry and will need to develop these skills over time.

While developing the curriculum, the last stage of Expand was important to include ensuring that the students are not just learning the information for the particular cases they were exposed to in the class. Providing the students with opportunities to take their learning and apply it to new situations grants them a challenge to explore, as well as, ensures they understand the new concepts on a deep enough level in which they are able to apply their new learning to this new situation. As Bybee (2014) points out, when pushing the students to expand their learning to new areas, it is important to make the new topic difficult enough that it is not an obvious answer but still attainable to the students. In the creation of this force unit, many questions in the worksheets have been designed to get the students to think deeper about what they learned in the activity and try to apply it to a new idea.
Learning that all types of inquiry are not the same but that they are all important in the process of learning through inquiry was another important understanding gained about inquiry. When learning about the four types of inquiry (confirmatory, structured, guided, and open) it became apparent that not all of these types would be present in the unit being designed. Because this is a first step into a fully inquiry-based unit, the students will require more guidance to learn how to explore before they can experience open inquiry. Because of this, there currently are limitations to this curriculum. In a sense, it is a stepping-stone to allowing students to learn through inquiry throughout the entire class. This early on unit in the school year will give the students an opportunity to start experiencing inquiry while other units throughout the year are modified and created to follow this inquiry model.

Utilizing a backwards design framework, specifically Understanding by Design (Wiggins & McTighe, 2005), provided an efficient way to create an engaging and effective unit plan. As Childre et al. (2009) explained, all students benefit from a backwards-designed curriculum. It makes sense that students will show better achievement when the learning goals and outcomes are established before the lesson plans are written. Allowing the lesson plans to be tailored to the intended outcomes instead of the assessments to be tailored to what was taught, ensures that the students are working towards intentional and well thought out learning targets.

Working through the force unit creation using the Understanding by Design (Wiggins & McTighe, 2005) framework proved to be effective in that there always seemed to be a clear direction to be heading. The details were not always easy to determine but the framework provided a methodical approach to creating the curriculum. Once the learning
objectives had been determined, the next step was to create assessments that would show mastery of these targets. Creating these assessments was not easy but the proven process was there to follow which allowed the formation of an effective unit. While creating the learning experiences it became evident that it is beneficial to work with and use other’s expertise to assist in creating effective lessons. This was done by discussing activities and questions with other teachers to find ways in which students can be challenged to think and explain as opposed to just looking up an answer. The culmination of this project was a completed unit of forces.

The Curriculum

The curriculum created, provides students with an opportunity to explore force and Newton’s Laws, with an end goal to find out how to use their new understanding of forces to allow an egg to fall and not break. Because learning through inquiry may be new to a majority of the students, most of the activities in the newly created unit are structured inquiry. In these activities, the students are provided with a question and procedure for different experiments in which they must make observations, take data, and then make conclusions based on the analysis of their data. An example of this in the unit is Force Activity 1 in which the students make observations of several situations that demonstrate Newton’s First Law well (Appendix D). These four situations show that an object at rest will stay at rest, or an object in motion will stay in motion, unless acted upon by an outside force, as Newton’s First Law states. One example from the activity is a note card sitting on top of a beaker or cup. A penny is then placed on top of the note card above the opening to the beaker. The students then flick the card out from under the penny and make observations about what happened. Each of the four situations have questions to keep the
students thinking about what they are observing. At the end, they must work together with their groups to determine what all of the situations have in common and if there is some sort of justification they can come up with to explain what they observed.

There is an opportunity for the students to experience guided inquiry when they work through Force Activity 2 (Appendix D). This activity is intended for them to explore how the mass of an object affects the force due to gravity. The students are posed with the following question: How does mass affect the gravitational force? Students are then tasked with writing a testable hypothesis based on their prior knowledge as well as a procedure that they believe will test this hypothesis. This activity will require more support from the teacher as the students will be trying to use their past experiences of conducting experiments to determine how best to investigate this question. The planning for this activity posed its own challenges, as the teacher needs to provide enough information to lead the students to explore the topic in a meaningful way. But, not so much information that the students still have to work through how to lay out the experiment. Because this unit is early on in the school year and the students are still learning about inquiry, there might be more support from the teacher in this guided inquiry activity as compared to possible future guided inquiry activities that could be developed for other units later in the year.

The culminating project for the unit is for the students to work in groups to design, build, modify, and then analyze a device to allow an egg to drop safely from a height of at least 3 meters (Appendix B). Working through this problem, the students will be exploring engineering processes of design, test, and modify their ideas. They will need to consider how forces act on an object when in a collision. This project will act as an Expand stage of
inquiry. Students will be taking what they learned throughout the unit and applying it in new ways. They will also be exploring concepts in engineering, which will be covered throughout the whole school year.

**Implementing The Curriculum**

With this curriculum being created in the summer, it will be important to share the results of the literature review with any teachers, whether they teach science or not, and the newly developed curriculum with those intending to teach the ninth-grade science class. Through sharing the results, other teachers will hopefully see the importance and benefits to the students’ learning and developing through the use of inquiry. When teachers see these benefits, they will be able to collaborate and build more curriculum together to get their students learning through inquiry.

Once this curriculum is implemented it will be important to assess its effectiveness on student achievement. To do this, student data about learning about forces from previous years will be compared to the students’ understanding at the end of the unit. Based on the research, it would be expected that the students will show none to some improvement over traditional teaching. The greater improvement should be seen in the students’ ability to be critical thinkers and problem solvers. This will be assessed through evaluating the students’ experimenting and analysis skills as they work through the different activities. Similarly, by assessing the students’ abilities to use data and evidence to design and modify their egg safety device will help show their growth in these critical thinking skills.

**Limitations**

As previously mentioned, the curriculum created is only a single unit out of an entire school year. This is not enough time for students to be comfortable and experienced
with learning through inquiry. This is a big limitation of the curriculum when it stands on its own. This inquiry curriculum needs to continue to be developed into other topics that will be covered throughout the school year in order for students to learn all the tools and skills necessary to learn through inquiry. Another limitation to this curriculum is that it was created and has not been tested out on an actual class yet. Like any curriculum or lessons, the teacher needs to be continually gauging student understanding and modifying their teaching if necessary. This curriculum will be no exception. While working through the planned unit, the teacher may find that certain topics need to be covered again in a new way or that extra practice is needed for students to truly understand the concepts and ideas.

**Implications And Future Work**

Creating this unit curriculum provides the background research and starting point to design and implement more inquiry based learning opportunities for ninth grade students. Taking this research and curriculum and sharing with other teachers will provide opportunities for collaboration to occur to continually improve and build on the work that has already been done.

Providing students with the opportunity to learn through inquiry will allow more students to become critical thinkers and lifelong learners. More students will be provided with the tools and strategies needed to solve problems and answer questions.

With more states adopting the NGSS, teaching through inquiry will become more applicable to meet state standards. The NGSS focuses more on the process of learning as opposed to the individual concepts, much like learning through inquiry. Implementing and sharing this curriculum can provide schools with a starting point to move away from
mainly content oriented learning. Schools and educational governing bodies can see the advantages to students becoming proficient in the learning process and require teachers to implement teaching styles that emphasizes this process over purely content.

Building from this project some questions arise that would be interesting to explore. One such question is, how effectively can teaching through inquiry be implemented in classes outside of science? Learning through inquiry is very tailored to work with science as it is essentially the same process that scientists go through to make discoveries. But, could this be implemented in a math class or an English class? Along these same lines, what would the effect on student learning and achievement be if all of their classes were taught through inquiry? It would be interesting to see if students show more growth through experiencing inquiry throughout their entire day. Finally, what are effective ways in which teachers new to inquiry can be supported in creating and implementing inquiry in their classroom? One of the big stumbling blocks for teaching through inquiry is teachers making the transition from a more traditional class. Are there tools and resources that could help a teacher make this transition easier?

**Summary**

This project has worked to answer the question: *How might student achievement be supported through inquiry-based teaching?* Using the curriculum described, students will have varying opportunities to experience inquiry in a ninth-grade general science class in order to build their skills as critical thinkers in the world. As can be seen in this section, there are many difficult aspects to creating an effective inquiry unit, such as, planning time for students to create their own explanations as opposed to the teacher telling them and creating engaging activities that will challenge the students to think about a specific
concept and want to dig deeper. But, with the proper support, such as the Understanding by Design framework, it is possible to methodically work through and create an engaging and effective end product.

Taking this new curriculum and literature review, and sharing with other teachers will allow for inquiry to grow and affect an even larger student population. With the push from many educational boards to focus on the learning process as opposed to purely learning content, it is clear that teaching through inquiry is a powerful tool to help students become critical thinkers and lifelong learners.
References


Muller, D. [Veritasium]. (2011, February 7) *The difference between mass and weight* [Video file]. Retrieved from https://www.youtube.com/watch?v=_Z0X0yE8loc


Appendix A

Understanding by Design Unit Template Completed for Force Unit
## Completed Understanding By Design Unit Template

<table>
<thead>
<tr>
<th>Title of Unit</th>
<th>Exploring Forces through Inquiry</th>
<th>Grade Level</th>
<th>9th Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curriculum Area</td>
<td>Forces</td>
<td>Time Frame</td>
<td>~3 Weeks</td>
</tr>
<tr>
<td>Developed By</td>
<td>Hans Harlane</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Identify Desired Results (Stage 1)

#### Content Standards

- **HS-PS2-1.** Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration (NGSS Lead States, 2013, p. 84)

- **HS-PS2-3.** Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision (NGSS Lead States, 2013, p. 84)

- Formulate a testable hypothesis, design and conduct an experiment to test the hypothesis, analyze the data, consider alternative explanations, and draw conclusions supported by evidence from the investigation (MN Dept. of Education, 2010, p. 27).

- Develop possible situations to an engineering problem and evaluate them using conceptual, physical, and mathematical models to determine the extent to which the solutions meet the design specifications (MN Dept. of Education, 2010, p. 29).

- Communicate, justify, and defend the procedures and results of a scientific inquiry or engineering design project using verbal, graphical, quantitative, virtual, or written means (MN Dept. of Education, 2010, p. 30).

- Recognize that inertia is the property of an object that causes it to resist changes in motion (MN Dept. of Education, 2010, p. 32).

- Explain and calculate the acceleration of an object subjected to a set of forces in one dimension \(F=ma\) (MN Dept. of Education, 2010, p. 32).

- Demonstrate that whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted by the second object back on the first object (MN Dept. of Education, 2010, p. 33).

---

<table>
<thead>
<tr>
<th>Understandings</th>
<th>Essential Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overarching Understanding</strong></td>
<td><strong>Overarching</strong></td>
</tr>
<tr>
<td>An object can be moving or stationary and have forces acting on it. When forces are balanced an object's velocity does not change. Unbalanced forces cause objects to accelerate.</td>
<td>How can an egg be dropped and not break? What is a system? How do we measure change? Why is understanding cause and effect important to your life? How can cause and effect relationships help predict or explain future events?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Related Misconceptions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>If an object has motion, it must have force acting upon this object. An active force is necessary to continue an object's motion at constant velocity regardless of its medium. It is assumed that there is a linear relationship between force and velocity instead of force and acceleration. (Demirci, 2005)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will know...</td>
<td>Students will be able to...</td>
</tr>
<tr>
<td>Key Terms: Force, Balanced, Unbalanced, Units of force. Variables influencing how an object accelerates when a force acts upon it.</td>
<td>Determine a system Identify the forces acting on an object.</td>
</tr>
</tbody>
</table>

**Assessment Evidence (Stage 2)**

**Performance Task Description**

| Goal | Have students design, build, and modify a device to allow an egg to safely fall from a height of 3 meters. Explain how their device minimizes the forces on the egg allowing it to land safely. |
| Role | The students will work in small groups (2-4) through this project. They will all take part in the design, building, testing, modifying, and analysis of the project. |
| Audience | The teacher and the rest of the class. |
| Situation | Figuring out a way to safely drop an egg. |
| Product/Performance | Egg safety device and a report describing their work and analysis of the forces acting on their device and why their device did or... |
Standards

HS-PS2-3. Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision (NGSS Lead States, 2013, p. 84)

Formulate a testable hypothesis, design and conduct an experiment to test the hypothesis, analyze the data, consider alternative explanations, and draw conclusions supported by evidence from the investigation (MN Dept. of Education, 2010).

Develop possible situations to an engineering problem and evaluate them using conceptual, physical, and mathematical models to determine the extent to which the solutions meet the design specifications (MN Dept. of Education, 2010).

Recognize that inertia is the property of an object that causes it to resist changes in motion (MN Dept. of Education, 2010).

Other Evidence

Pre assessment:
- Initial student discussion about what they think a force is.

Formative assessments:
- Force Worksheets – These worksheets will be completed by the students after they have experiences a concept and as a class we have come up with an explanation for it. They are intended to get the students to think deeper about what they learned, practice what they have learned, and for the teacher to use as a formative assessment to gauge student understanding.
- Exit questions
- Question posed at the beginning of class

Summative assessments:
- Unit test in which students will have a few questions about key vocabulary and concepts they learned about as well as data to analyze and draw a conclusion from.
- Egg Drop project. Design a device to allow an egg to fall and land safely. An analysis of the forces acting on the egg will be required. What forces are acting on the egg before it falls? What forces are acting on the egg as it falls? What forces are acting on the egg as it lands? How do you get the egg to land safely? What are you doing to the forces?

Learning Plan (Stage 3)

| Where are your students headed? Where have they been? How will you make sure the students know where they are going? | The previous unit was all about motion. Students learned what constant velocity and acceleration looks like for an object. The students are heading towards an |
understanding of how forces are acting on objects in the world around us. They will then be learning how these forces affect object’s motion.

- To ensure students know where they are headed, essential questions will be posted for them to see each day. These are questions they should not be able to fully answer at the beginning of the lesson but will feel comfortable answering after the learning experience is complete (this can take from part of a lesson to a few days)

| How will you hook students at the beginning of the unit? | • Introduce Egg Drop Challenge in which they will be designing and building a device able to allow an egg to be dropped from a height of 3 meters and not break. They will need to learn about forces first in order to understand how to make the best design.
  • Broomball activity |
| --- | --- |
| What events will help students experience and explore the big idea and questions in the unit? How will you equip them with needed skills and knowledge? | • Broomball activity  
• Force Activity 1 – focusing on Newton’s First Law  
• Force Activity 2 – focusing on Newton’s Second Law  
• Force Activity 3 – focusing on Newton’s Third law |
| How will you cause students to reflect and rethink? How will you guide them in rehearsing, revising, and refining their work? | • Homework worksheets will require them to rethink about the concepts they learned in class. They will be expected to take what they observed, what we talked about in class, and the explanations they came up with and apply them to new situations. |
| How will you help students to exhibit and self-evaluate their growing skills, knowledge, and understanding throughout the unit? | • Students will have to share their current understanding with their groups and the class. They will need to practice conveying what they think and know to others in a comprehensible manner. |
| How will you tailor and otherwise personalize the learning plan to optimize the engagement and effectiveness of ALL students, without compromising the goals of the unit? | • There will be several opportunities for student choice throughout the unit.  
• Activity 2 will provide an opportunity for students to develop their own experiment to answer a given question  
• The final project will provide students with the freedom to be creative while trying to create their egg safety device. |
| How will you organize and sequence the learning activities to optimize the engagement and achievement of ALL students? | • The unit will flow from a basic understanding and definition of a force to experiencing and building definitions to Newton’s three laws. |
Appendix B

Force Unit Assessments
Egg Drop Challenge

Name: ________________________________
Due Date: ________________

You are tasked with creating a device to safely drop an egg from a height of 3 meters.

**Materials:**
Egg, rulers, scissors, and glue

**You can choose 12 materials from the following list**

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardboard (10” x 10”)</td>
<td></td>
</tr>
<tr>
<td>Elastic bands – 5</td>
<td></td>
</tr>
<tr>
<td>Popsicle sticks - 8</td>
<td></td>
</tr>
<tr>
<td>Sponges - 2</td>
<td></td>
</tr>
<tr>
<td>Construction paper - 2</td>
<td></td>
</tr>
<tr>
<td>Ziploc bags - 2</td>
<td></td>
</tr>
<tr>
<td>Bendy straws - 20</td>
<td></td>
</tr>
<tr>
<td>Styrofoam cup - 1</td>
<td></td>
</tr>
<tr>
<td>Poster board (10” x 10”)</td>
<td></td>
</tr>
<tr>
<td>Cotton pads - 6</td>
<td></td>
</tr>
<tr>
<td>Q-tips - 15</td>
<td></td>
</tr>
<tr>
<td>Toilet paper - 20 squares</td>
<td></td>
</tr>
<tr>
<td>String – 30cm</td>
<td></td>
</tr>
<tr>
<td>Wires – 10cm</td>
<td></td>
</tr>
<tr>
<td>Spaghetti - 20</td>
<td></td>
</tr>
<tr>
<td>Balloons - 2</td>
<td></td>
</tr>
<tr>
<td>Paper Plate - 1</td>
<td></td>
</tr>
<tr>
<td>Tissue paper - 5</td>
<td></td>
</tr>
<tr>
<td>Plastic wrap (12”x12”)</td>
<td></td>
</tr>
<tr>
<td>Cotton balls - 10</td>
<td></td>
</tr>
<tr>
<td>Toothpicks – 20</td>
<td></td>
</tr>
<tr>
<td>Paper – 4 (8 ½” x 11”)</td>
<td></td>
</tr>
<tr>
<td>Aluminum foil (12” x 12”)</td>
<td></td>
</tr>
<tr>
<td>Newspaper – 1 full page</td>
<td></td>
</tr>
<tr>
<td>Newspaper – 1 full page</td>
<td></td>
</tr>
<tr>
<td>Masking Tape - 40cm</td>
<td></td>
</tr>
</tbody>
</table>

Bag or small box to hold materials.

**Specifications:**
- You can only use the above listed materials
- You must be able to put the egg into and take the egg out of your device. You can’t build the device completely around it.
- The egg safety device must fit on an 8 ½” x 11” piece of paper

**Added Challenge**
The minimum requirement is to get your egg to safely land from a height of 3 meters. See how high your device can safely protect your egg. If you would like to take the challenge the drop height will increase in 1-meter increments. Your egg will need to survive the drop before going to the next height.
Procedure
1. Design and construct your egg safety device
2. Test and modify your device
   a. The drop zone will be open after the first workday to provide opportunities to test your design.
3. Final Drop
   a. The final drop test will be ______________. Your egg safety device must be ready for this day.

Analysis and Report
A report of your work will be due the day after the egg drop.
Each person will turn in their own report, but you can work together with your group.
The following items need to be included in your report

Pre-Drop
• Original sketch of your egg safety device idea
• Why are you designing it the way you are? Explain specific components.
• Results from test drop. What did you learn from doing this?
  o What modifications were made based on these results?

Post-Drop
• What forces are acting on the egg device:
  o Before it is dropped?
  o While it is falling?
    o When it hits the ground?
• How much force is the ground applying to the egg device when it hits the ground? Explain how you know this.
• What about your design allowed your egg to not break or caused it to break? Be specific.
• If you had more time and another drop, what would you change about your design?
• Explain how aspects of your device could be used in a real world application.
• The report must be well organized and neat. Use diagrams, pictures, and tables when appropriate to make your information clearer.

Personal Reflection
What was the hardest part of the process? What did you do to get past it?
Where did your design idea come from?
Egg Drop Rubric

Name: ____________________________________________

Group Members: ________________________________
______________________________
______________________________
______________________________

<table>
<thead>
<tr>
<th></th>
<th>Building Understanding</th>
<th>Approaches Expectations</th>
<th>Meets Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg Drop Test</td>
<td>6 points Egg broke</td>
<td>8 points Eggshell cracked but did not break</td>
<td>10 points Egg did not receive damage from 3m drop</td>
</tr>
<tr>
<td>Pre-Drop Analysis</td>
<td>2 point Two components from Meets Expectations are missing.</td>
<td>4 points One component from Meets Expectations missing. Or, no modifications made.</td>
<td>5 points All the required components of the Pre-Drop analysis are included.</td>
</tr>
<tr>
<td>Post-Drop Analysis</td>
<td>10 points Three or more components from Meets Expectation missing or not fully explained</td>
<td>13 points One to two components from Meets Expectations missing or not fully explained</td>
<td>15 points All the required components of the Post-Drop analysis are included.</td>
</tr>
<tr>
<td>Personal Reflection</td>
<td>2 points Two or more components from Meets Expectation missing.</td>
<td>4 points One component from Meets Expectations missing.</td>
<td>5 points All required questions are thoroughly answered.</td>
</tr>
</tbody>
</table>
Forces Test

Name: ___________________________

For the following 7 questions choose from the terms in the box to the right.

1. This law means when a mass has a force applied to it the mass accelerates

2. Term that means a resistance to change

3. This law means equal and opposite forces to every applied force

4. This law means moving objects keep moving

5. This law means objects at rest stay at rest

6. A push or pull

7. An attractive force between objects. Gravity

8. What is the acceleration due to gravity?
   A. 8.9 m/s/s
   B. 9.8 m/min/min
   C. 9.8 m/s/s
   D. 9.8 miles/s/s

9. If a boat has a mass of 450 kg and accelerates at 20 m/s/s, what is the force?
   A. 9,000 N
   B. 90 N
   C. 9 N
   D. 9,000,000 N

10. If a 4,000-kg car is traveling East on County Road E and its brakes are applied to stop the car before it hits a pedestrian. The brakes apply a force of -32,000 N, what is the acceleration of the car?
    A. 8.00 m/s/s
    B. -8.00 m/s/s
    C. -80.00 m/s/s
    D. 80.00 m/s/s

11. How would you describe the forces acting on the car in question number 10?
    A. Unbalanced Forces
    B. Balanced Forces
    C. No Forces
    D. Supernatural Forces
12. During the broomball activity a student gives the bowling ball a brief push. After the push what forces are acting on the bowling ball?
   A. The force of gravity
   B. The force of gravity and the force from the push
   C. The force of gravity and the normal force
   D. The force of gravity, the normal force, and the force from the push

13. After the bowling ball has been pushed by the broom, and the broom is no longer touching it, which of the following describe its motion? Assume that there is no friction.
   A. The ball slows down gradually to a stop
   B. The ball moves at a constant speed
   C. The ball accelerates constantly
   D. The ball continues at a constant speed for a while, and then slows down.

14. Which of the following is an example of Unbalanced Forces?
   A. A bicycle slowing down as it goes down a hill
   B. A bicycle travelling at a constant speed as it goes up a hill
   C. A bicycle travelling at a constant speed as it goes down a hill
   D. A bicycle sitting stationary on a hill

15. Which of the following statement is the best example of inertia?
   A. It is really hard to stop a really big rock rolling down a hill
   B. It is really hard to start rolling a really big rock that is not moving
   C. It is really hard to make a really big rolling rock change direction when it is rolling
   D. None of the examples are good examples of inertia
   E. All of the examples are good examples of inertia

Identify the following statements as examples of Newton’s (a) 1st, (b) 2nd, or (c) 3rd Law of Motion

16. If you are riding your bike and your front tire gets stuck in a rut you fly over the handle bars.

17. You throw a 20 kg rock and a baseball with the same amount of force, the baseball goes farther.

18. Sarah is on a skate board. She pushes on a wall to roll backwards.

19. Pulling a table cloth out from under plates, glasses, and silverware; and everything stays where it was.

20. Frank pushes off the edge of a boat while jumping onto a dock. The boat moves away from the dock as he pushes off.
21. A semi-truck and a car are involved in a head on collision. Compare the **force the semi-truck applies to the car** to the **force the car applies to the semi-truck**. Use Newton’s Laws to explain your answer.

22. A 0.250kg baseball is in freefall (not at terminal velocity). How much force is gravity applying to the baseball? **SHOW YOUR WORK**

23. When a hammer strikes a nail the hammer exerts a force on the nail. According to Newton’s third law, the nail exerts the same force back onto the hammer. Why does the nail go into the board as opposed to the hammer just bouncing off?

24. Your friend Jan claims “an object always moves in the direction of the net force that is exerted on it.” Come up with an experiment that could test Jan’s claim.
   
   A. Write a hypothesis that could be used to test her claim.

   B. Write a procedure to test your hypothesis.
Appendix C

Force Unit Lesson Plans and Teacher Notes
## Sequence of Learning Experiences

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
</tr>
</thead>
</table>
| - What are forces?  
- What variable affect forces?  
- Broom Ball activity  
- Extension from Broomball activity | - Force Activity 1  
- Newton’s 1st law  
- Constant velocity vs stationary objects.  
What forces?  
Start identifying forces acting on an object | Practice identifying forces | Net force  
Force diagrams | Force Activity 2  
Gravitational force vs mass lab  
(Newton’s 2nd law) |

<table>
<thead>
<tr>
<th>Day 6</th>
<th>Day 7</th>
<th>Day 8</th>
<th>Day 9</th>
<th>Day 10</th>
</tr>
</thead>
</table>
| Discuss Force Activity 2  
Mass vs Weight | Connect to Newton’s 2nd law.  
Applications of 2nd law | Force Activity 3  
Newton’s 3rd Law activity | 3rd law discussion | Application of 3rd law |

<table>
<thead>
<tr>
<th>Day 11</th>
<th>Day 12</th>
<th>Day 13</th>
<th>Day 14</th>
<th>Day 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start egg drop work</td>
<td>Egg Drop work day</td>
<td>Egg Drop work day</td>
<td>Egg Drop/analysis day</td>
<td>Review Forces</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Day 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forces Test</td>
</tr>
</tbody>
</table>
Teacher Notes

The following pages outline the sequence of activities for the force unit. These notes include details about each activity. They include notes on how to set up the activity and to hold a discussion after to help all students build an understanding of the concept being explored. Each day has an essential question(s) listed that should be posted for the students to see. These questions are ones that the students should not be able to fully answer yet, but will be able to after the learning experiences. Periodically throughout the unit the students will be asked to put their answers to labs and assignments on whiteboards to share with the rest of the class. This works well to have several personal sized white boards for the students to use (~3’ x 2’ in size).

Day 1

Essential Question: How can an egg be dropped and not break? What is a force?

- Start the lesson by having students discuss with their table partners what they think a force is. Bring the discussion to the whole class and write ideas on the board.
- Introduce that they will be studying forces for the next several weeks with an ending project of finding a safe way to drop an egg from a height of 3 meters.
- To start exploring forces the students will play a broomball game. Emphasize that they need to make observations while they are playing.
INQUIRY BASED FORCE UNIT FOR NINTH-GRADE SCIENCE

Broomball Activity

This introductory activity gets students to start observing forces. It gives them an experience to refer back to once we start discussing forces.

Materials:

- 2 brooms
- 2 bowling balls
- 2 buckets with sand (or some other heavy object)
- Blue painters tape (comes off the floor easier than masking tape)

The Course

Setup two identical courses, or more if you have the supplies as more groups will get more students involved quicker. The following diagram is an example. Be creative with the supplies available but make sure to include a No Touch Zone.

How the game is played.

- Split the class into 2 even teams.

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• Each team will have their own course, broom, and ball.
• The game is a relay in which one person starts at one end and must move the bowling ball through the course to the other end where they pass the broom to a teammate who takes the ball back through the course with the broom.
• This repeats until everyone on each team has gone through the course.
• There is a 1 second penalty for every time the ball touches an object other than the bristles of the broom.
• Take the time it takes each team to complete the course and add on any time penalties to find the fastest team.

Small group discussion
• In groups of about 4 students have them discuss the following two questions
  o What was difficult in the broomball activity
  o How did you use the broom to overcome these difficulties?

Large group discussion
• After the small groups discuss, have the whole class discuss the difficulties and solutions with the broom.

Difficulties they should come up with
• Getting the ball to start
• Getting the ball to stop
• Getting the ball to turn

On a sheet of paper have the students individually write down what determines the path of the ball in the no touch zone. After everyone has had a chance to write their ideas have them share with each other then the class.
Using what they've seen and discussed have the students help define what a force is. (A push or a pull)

**Extension from Broomball Activity**

Give each table group of 3-4 students a ball to roll (tennis ball, racket ball, bouncy ball, etc.). Have one person give the ball a push so it rolls from one side of the table to the other. As a table, have them discuss and make predictions on the worksheet where and what forces are being applied to the ball. Consider 3 locations: when the ball is in contact with the person’s hand, when it is rolling along the table, and when it is stopped on the other side.

- This activity should start to show misconceptions about forces being required to keep an object moving. Have all the groups work through the activity and then as a class they will discuss what they observed.
- Have groups use a whiteboard to draw the forces acting on the different objects in the different situations. No formal teaching of force diagrams has happened yet so this will just be the students’ ideas at this point. With all groups holding up their boards for everyone to see, ask people to share similarities and differences between the drawings. Help lead them to drawings that show the forces starting at the object and pointing away.
- Get students to note that there is a gravitational pull from the Earth on the ball. Even when the ball is not touching the Earth there is still the pull.
- Also get them to notice that there is not a force that is keeping the ball moving across the table after they push it.
- After groups have discussed their force diagrams and findings start working towards a unified force diagram. Show students how physicists draw force
diagrams. Represent object as a point source and show the direction and magnitude of forces acting on the object. Use examples from the student work to show how force diagrams are drawn. The following situations are good to use.

- Ball just sitting on the desk
- Ball being pushed on the desk
- Ball rolling on desk (not being pushed)
- Ball falling off the desk
Day 2

**Essential Question**: How do forces affect an objects motion?

- Have an object (e.g. an apple) sitting on a table up front for everyone to see. Have the students discuss with their table partners what forces, if any, are acting on the apple. Have them create a list to share with the class. Discuss with the class and make a class list of forces. This should be review from the Broomball Extension activity discussion. The idea here is to see if students are able to identify that there is a force from the Earth pulling down on the object and a force from the table pushing up on the object. Even though it is not moving there are still forces acting on the object.

- Introduce **Force Activity 1**. Demonstrate each of the activities they will be doing and making observations of. Have students work in groups of 3-4 through the activities. Circulate through the room asking clarifying questions about observations they write down. Make sure that they are recording as much detail as possible.

- Once through the activities discuss student observations and answers to analysis questions as a class. Help facilitate the discussion to define Newton’s 1st Law.
  - Students should observe that once an object is moving it will keep moving until something stops it. And that if an object is not moving that it will not start moving unless a force acts upon it. Keep the students discussing their observations until these points are fleshed out. These ideas can then be connected to Newton’s 1st Law.
  - Newton’s 1st Law – An object at rest stays at rest and an object in motion stays in motion, unless acted upon by an outside force.
Day 3

Essential Question(s): How are forces represented? What is a system?

- Hook/question – What are some real world experiences you have had that show what you observed in the lab yesterday?
- Have each lab group draw the force diagrams for each of the four situations in Force Activity 1 on whiteboards. Share all boards with the class and have them make observations of similarities and differences. Work with the class to come to a consensus about the force diagrams for each situation.
- Practice identifying forces and drawing Force Diagrams.
  - An object on an inclined plane – emphasize that the normal force is not always opposite the gravitational force. Can add friction as well
  - An object hanging from a rope – emphasize the tension force.
  - An object being pulled upwards at a constant velocity – emphasize that the net force must be zero to have a constant velocity.
  - An object being pulled across the floor at a constant velocity – emphasize that the net force must be zero to have a constant velocity.
  - A skydiver has just jumped out of a plane and is accelerating downward – emphasize that the net force will not be equal.
- Force Worksheet 1. Homework problems to practice what they have learned.
- Exit question to gauge understanding so far. Possibly - What questions do you have about force diagrams?
Day 4

**Essential Question(s):** How are forces represented? What is a system?

- Question on the board for the students to write in their notes and write an explanation for why they think it happens.
  - When a car is struck from behind (rear ended), the passengers feel like they are jolted back into their seats. Why would the passengers be jolted backwards and why are headrests important in this situation? Use evidence/data to support your answer.

- Go over homework – for them to learn from, it is still practice at this point.
  - Start by having each table group discuss their answers as a table. They should discuss any differences they find among their worksheets.
  - Then pick a few problems to have them write their group answers on a whiteboard to share with the class. Have all groups hold up their whiteboards at the same time and have students discuss differences and similarities they observe.

- Have students work in groups and create force diagrams on whiteboards for the following situation. Give students time to make their diagrams and then share and discuss their answers.
  - A basketball in the middle of a free throw.
  - A water skier going at constant velocity.
  - An airplane slowing down as it flies towards the runway.
  - A box being pushed across the floor. The box is accelerating and there is friction.
An egg falling.

- Exit question – On a piece of paper draw the force diagrams for the following two situations. Collect once students are done.
  - A dog sitting on an inclined plane
  - A car slowing to a stop.
Day 5

Essential Questions: How do we measure change? How can we affect a system to change the forces acting on it?

• Variables that affect the force of gravity? Have students come up with any ideas as to what variables they think may affect the force of gravity on an object. Make a class list of ideas on the board. Write any ideas students come up with on the board. As a class, discuss through the list and remove any that seem unrelated or would be too hard to test in a high school classroom. Make sure that mass, or at least weight, is on the list. Today’s activity is going to be exploring how mass affects the gravitational force.

• Experiment design. Discuss with the class what makes a good experiment. This should be review from previously in the year. Main topics to make sure to cover:
  o Only changing one variable. Identify an independent and a dependant variable.
  o Repeated tests, more data is better. Make a table for your data.
  o How will you graph your data?
  o Make observations.

• Hand out Force Activity 2 and have the students answer the first question and write a hypothesis. They should try it first on their own and then compare their answers with their table partners. Make sure everyone has a hypothesis written down before moving on. Many forms of hypotheses are acceptable but a good form is the If ......., Then ......., Because ......... This gives an easy format for students to make a prediction. Have each group come to a consensus on a hypothesis. Each group will
then share their hypothesis with the class to hear what all of the groups are thinking.

• Next show the students some lab supplies available to the students for the lab. A list of possible items are:
  
  o Mass sets
  o Spring scales
  o Triple beam balances
  o Force sensors

Make sure to include some sort of variable mass and some way to measure the force, be it a force sensor or spring scales. More items can be added that may seem unrelated to get the students thinking about what are the necessary materials to answer the given question. If there are even more supplies in the class it is good to let the students know that they can ask for other materials and they can be made available to them if they exist in the class.

• With their lab partners, groups of 3-4, have them work together to come up with a procedure and needed materials to test how the mass of an object affects the gravitational force. Once they have a procedure, they need to get it checked off by the teacher before getting their materials. Make sure that they have a plan for how they will collect data in a data table and how they plan to graph it. The teacher’s role in checking the procedure is to make sure that the students are able to collect data, not whether the data will lead to the correct answer.

• Have the students conduct their experiments and collect data.
• The intended learning outcome from the lab is to explore how increasing the mass increases the force applied to it by gravity. When plotted correctly this will lead to a graph with a linear formula of \( F=ma \). Try to make sure a few groups have procedures that will lead to this result if possible.
**Day 6**

**Essential Question:** How do we measure change? How can we affect a system to change the forces acting on it?

- **Hook/Question:** How does mass affect the gravitational force?
- **If needed give students time to finish analysis from yesterday’s activity.**
  - Get students to graph their data and find the slope of their data.
    - This may need to be an explicit teaching moment by the teacher if the students are unsure how to get the slope. They should be somewhat familiar with graphing and slope as they have already worked with it during the motion unit.
- **Discuss Force activity 2**
  - This discussion can go many different ways as students will most likely have gone about answering the question in different ways.
  - Have groups sketch their graphs and any important analysis on their whiteboard to share with the class. Post all whiteboards up front and have the class make observations and comparison between the different boards.
    - Students should be sharing their observations with the class and can be asking other groups questions about their data/analysis.
  - Help guide the students to see the equation of the line from their data should be \( F=(9.8 \text{ N/kg})m \). Can then change the units to \( F=(9.8\text{ m/s}^2)m \)
- **Build understanding towards Newton’s 2\(^{nd}\) Law**
  - \( F=ma \)
- **Differentiate Mass vs. Weight**
- This video can be shown to help students understand the difference
- Veritasium – The Difference Between Mass and Weight (Muller, 2011)
  - [https://www.youtube.com/watch?v=Z0X0yE81oc](https://www.youtube.com/watch?v=Z0X0yE81oc)
- **Force Worksheet 2** – This can be started at the end of class if time otherwise will be homework.
Day 7

**Essential Question:** How do we measure change? How can we affect a system to change the forces acting on it?

- Question for student to work on at the beginning of class.
  - How would the force of gravity be different on a different planet? Or would it be the same as Earth? Explain.
  - After students have time to think about the question and discuss as a class, give actual planet masses for them to consider.
    - Earth’s mass = \(5.97 \times 10^{24}\) kg
    - Mars’ mass = \(0.642 \times 10^{24}\) kg
    - Saturn’s mass = \(568 \times 10^{24}\) kg
  - Start explaining scientific notation if they have not seen this before. This does not need to be a big discussion at this time but make sure to explain it so they can at least understand it in this situation. They will be exposed to it again later in the year.
    - How would this mass effect the acceleration of a falling object?
- Go over Force Worksheet 2
  - Assign different homework questions to different groups. Have them write the solution to their assigned problem on a personal whiteboard.
  - Have each group present their whiteboard to the class allowing for class discussion to help get to the correct answer.
- Applications of Newton’s 2\(^{nd}\) Law
Materials needed: Dynamics cart that a person can ride on, large dial spring scale, and stopwatch.

In their groups have students discuss what would happen if the same force were applied to pull different masses on the dynamics cart.

- Discuss what groups predict as a class.

Test out the predictions using three different students. Small, medium, and large. Have another student pull the student on the dynamics cart with the spring scale trying to keep the force constant. The rest of the class should time them to see how the times compare. Also have them observe the motion of the cart. Is it a constant speed or is it accelerating?

- Connect this back to F=ma, when the force is constant

Next, have the groups figure out how to get two masses to accelerate at the same rate. Give two masses for them to use. This can be two masses of students (and the cart) or some different masses that will be placed on the cart. In their groups they should work through their solution on a whiteboard, making sure they also put their work in their notebooks. Once all the groups have a solution put all the whiteboards up front and have the class make observations of similarities and differences. Work towards a class consensus for what force must be applied to each situation. And finally test the situation to see if they are correct.
Day 8

**Essential Question:** What happens when an object exerts a force on another object? Why is understanding cause and effect important in your life?

- Have students start the class by pushing down on their desk with a small force.
  - Pose the question “Is the desk pushing back? If so, how do you know?”
  - They should feel it as their fingers bend
- Have them push again but this time with a larger force.
  - “How does this force compare to the force you felt when you pushed less?”
  - It should seem like a larger force.
- Express to the students that today they are going to be exploring the forces of objects interacting with each other.

**Force Activity 3**

- Show the class how to connect the spring scales so they pull on each other.
  - Do not over stretch the spring scales.
  - Make sure everyone in your group has a chance to try pulling on the spring scales in different pairings so they all can experience the lab.
- If time, can start discussion of the lab. If not this is planned for the next day.
Day 9

**Essential Question:** What happens when an object exerts a force on another object? Why is understanding cause and effect important in your life?

- Have a student stand on a skateboard and push away from the wall.
  - “Why does the student move away from the wall?”
  - “Was there a force applied to the student?”
- Connect Force Activity 3 to Newton’s 3rd Law
  - Go through Force Activity 3.
    - Start identifying that for every force there is an equal and opposite force.
    - Have lab groups make whiteboards of their results for Force Activity 3. Place all the boards up front and discuss the results as a class.
    - If students are still somewhat confused or do not quite get the third law pairs yet that is ok as they will be exposed to more examples.
  - Using two force sensors and a lab interface such as Logger Pro connect the two sensors so that they will pull away from each other.
- Make sure to switch the direction of one of the force sensors as it is facing the opposite direction as the other sensor.
- Pull the sensors apart with varying degrees of force and plot out the force over time.
- Do the same except put bumpers on the sensors and push them together.

Here is what a sample graph of the force sensors should look like. Note that one force sensor is reading negative due to its orientation (this was needed to be set first)

- **Force Worksheet 3** – start in class if time and assign as homework.
Day 10

**Essential Question:** What happens when an object exerts a force on another object? Why is understanding cause and effect important in your life?

- Blow up a balloon. Hold the end so the air will not escape. Ask the students what would happen if the balloon were let go.
  - What direction is the force being applied? Why does the balloon fly off?
  - Identify the third law pairs.

- Go over Force Worksheet 3
  - Assign different homework questions to different groups. Have them write the solution to their assigned problem on a personal whiteboard.
  - Have each group present their whiteboard to the class allowing for class discussion to help get to the correct answer.

- Application of Newton’s 3rd Law
  - Two students sit on dynamics carts (or chairs with wheels). Try to pick two students with notably different masses. Have the students connect together by holding a rope.
  - Start with the students spread apart, facing each other, and have them do the following tasks. Make note of where each person starts and stops in each situation.
    - Person A holds the rope and Person B pulls.
    - Person A pulls the rope and Person B just holds it.
    - Both Person A and Person B pull the rope.
o Have a discussion with the class about if Newton's Third Law is violated, as both people do not go the same distance.

o Can refer back to Newton's Second Law and how that law may be affecting the situation.

• Field forces

  o All of the 3rd law pairs they have investigated so far have been contact forces.

  o See if students can come up with forces that are not contact forces and if they can identify the pairs.

    ▪ Gravitational – Ex. Earth and Person. The Earth exerts a force on the person and the person exerts the same force in the opposite direction on the Earth

    ▪ Magnetic – Forces of attraction or repulsion depending on the sides of the magnet.

      • Pass out magnets for students to experience the push or pull force. Have them note that the push or pull should feel equal.

      ▪ Make sure students make notes about these different forces.

  o Have students practice identifying third law pairs in different situations.

    ▪ Start by having students write down as many third law pairs as they can think of.

    ▪ Have them share their ideas with their group. They can then pick their favorite from everyone’s ideas.

    ▪ On a whiteboard, identify the third law pairs and draw the force diagram for each of the objects in the system.
- Each group will then share their whiteboard with the class.
Day 11 – Day 13

Essential Question: How can an egg be dropped and not break?

• Hook – Drop an egg to show it breaking?
• Introduce Egg Drop Challenge in detail
  o Go through the Egg Drop Challenge worksheet with the class so they know what is expected and what guidelines for the project are
  o Explain the timeline of building, testing, modifying, and then the final egg drop test.
  o Go through what they will be turning in at the end so they can be thinking about the questions while they are working.
• Work time on Egg Drop Challenge
• On the second workday, have a drop zone set up in which they can do some tests.
  o For these tests it might be better to use something (like a rock about the same size and weight as an egg) as a stand in, instead of an egg, unless you have a lot of eggs.
  o Plan to have two eggs for each group. One that they could do a test with and one for the final drop test. Let the students know this for testing so they feel somewhat confident before they do their first test.


**Day 14**

**Essential Question:** How can an egg be dropped and not break?

- Egg Drop test drop day.
- Give about 10 minutes for groups to make sure everything is set with their egg drop device. Have them place their egg into their device so it is all ready to go.
- Go through the egg drops with the whole class watching to help build excitement.
- Drop them one at a time from a height of 3 meters and inspect them to see if they survived or not.
- Then, those that survived unharmed can be tested from a height of 4 meters. Continue until all eggs have broken or you have reached the highest height available.
- Some possible ideas for places to do the drop test
  - In a stairwell
  - Outside or in a gym dropping off the side of the bleachers (with a tarp on the gym floor)
  - Inside or outside using a ladder
  - From the roof if there is safe access.
  - There may be other options. Talking to custodial staff may help with determining viable locations.
- After all of the test drops are complete, have the groups start working on their analysis and lab write up.
Day 15

- Collect egg drop analysis and conclusions
  - Hold a class discussion about what students learned about how to safely allow their egg to fall without breaking.
  - Were there common concepts/components to projects that worked? Didn't work?
  - What would students do to improve their projects?

- Review Forces
Day 16

- Test on forces
Appendix D

Force Unit Activities and Worksheets
Broomball Extension Activity

Name: ______________________________________

Place a book at one end of your table. Give the ball a push on the other end of the table and observe it roll across.

At each of the following points of the ball’s trip across the table indicate/label all the forces you think are acting on the ball.

1. While the ball is being pushed.

2. After the ball was pushed and is rolling across the table

3. When the ball hits the book and stops.
Now remove the book so the ball will fall of the table. Do the same procedure but allow the ball to fall off the table.

Again, at each of the following points of the ball’s trip across the table indicate/label all the forces you think are acting on the ball.

4. While the ball is being pushed.

5. After the ball was pushed and is rolling across the table

6. After the ball has gone off the table. **Draw** the path of the ball as it goes off the table.
Analysis
1. In situations 1-3 what forces did you identify?

2. In situations 4-6 what forces did you identify?

3. Why does the ball fall off the table? What is causing it? How do you know?

4. Based on your observations in situation 6 is there anything you need to add to the other situations?

5. Does something have to be touching the ball in order for a force to be acting on it? Explain why or why not (Use data/observations to help explain)

6. If an object moving to the right experiences a net force pushing to the right, explain what would happen to the motion of the object.

7. If an object moving to the right experiences a net force pushing to the left, explain what would happen to the motion of the object.
Forces Activity 1

Name: ____________________________

What is a force?

Explain where you have experienced a force.

In this activity you will be making observations of four different scenarios. Make sure to record any observations.

Part A: Coin in a Cup

Procedure:
1. Place an index card on top of a cup. Place a coin on top of the card.
2. Figure out a way to get the coin to land in the cup by only touching the index card.

Observations/Notes:

Analysis and Questions:
1. What did you have to do to get the coin to land in the cup?

2. What do you need to do to get the coin to not land in the cup?

3. What are differences in what you do between getting the coin in the cup or not in the cup?

4. Draw a picture and identify the forces acting on the different objects
**Part B: 2 Liter Bottle and Paper**

**Procedure:**
1. Place a piece of printer paper so half of it is on the table and half is hanging off.
2. Place a 2-liter bottle full of water on top of the paper.
3. Quickly pull the paper downward.

**Observations/Notes:**

**Analysis and Questions:**
1. What did you observe about the paper and bottle as you pulled the paper out quickly?

2. What would happen if you did not pull the paper quickly? Explain.

3. Draw a picture and identify the forces acting on the different objects

**Part C: A Car Down a Ramp**

**Procedure:**
1. Create a ramp using textbooks and a whiteboard.
2. Place a cart on the ramp and balance a coin on top of the cart. If the coin does not stay on the cart before the cart is released then lower your ramp.
3. Place a book at the end of your ramp to stop the cart.
4. Let your cart roll down the ramp and record your observations.

**Observations/Notes:**

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**Analysis and Questions:**

4. What did you observe about the cart and coin as it rolled down the ramp?

5. What did you observe about the cart and coin once it collided with the book?

6. Draw a picture and identify the forces acting on the different objects

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**Part D: Marble in a Box**

**Procedure:**

1. On the level table, place the marble in the middle of the box.
2. Start moving the box quickly

What did you observe about the box and the marble?

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3. Can you move the box in a way that would allow the marble to not move?

If possible, how did you do this? If not, why do you think you couldn’t?
4. With the marble at the back of the box get the box moving.
5. Suddenly stop the box.

What did you observe about the box and the marble?

6. Draw a picture and identify the forces acting on the different objects in the above three situations.

**Activity Analysis**

1. Based on your observations from the four activities, what is necessary for an object to start or stop moving? Be specific and use examples/data/observations from the activity to support your answer.

2. What characteristic/property of the objects do you think cause the observations you saw in the lab? Why do you think so?

3. Come up with a real world example where you have experienced the observed phenomena.
Force Worksheet 1

Name: ________________________________

1. Draw a picture and identify the forces acting on a ball rolling down a hill.

2. In your own words explain Newton’s First Law.

For the following questions make sure to include data/observations from the activities we have done in class or from life experiences to help explain your answers.

3. If you were out in space and threw a baseball, how much force would need to continue to push on the ball in order for it to keep moving?

4. You place a soccer ball in a wagon to go to the park. You accelerate the wagon forward quickly.
   a. Describe the motion of the ball relative to the wagon.

   b. Describe the motion of the ball relative to the ground.

5. Why is it important to wear seatbelts when riding in a car? Use Newton’s First Law in your explanation.
Force Activity 2

Name: ________________________

Question: How does mass affect the gravitational force?

1. For this problem, which variable is the Independent variable? ____________________
   Dependant variable? ____________________

Hypothesis: Write a hypothesis for how you expect mass to affect the gravitational force.
(Make sure it is testable)

Procedure:
With your table partners come up with a procedure that will test your hypothesis. Make sure to be specific with your steps. Once complete get your procedure checked off to get your materials.

Materials:
List all the materials you need to conduct your experiment.
Observations/Data Table(s):

Analysis (Use a computer to create a graph of your data to help with the analysis):

Conclusions and Questions: Using your data as evidence, write down any conclusions you can make along with any questions that arose from your experiment.
Force Worksheet 2

Name: ____________________________

1. In your own words explain Newton’s Second Law.

2. A little girl pulls her wagon with her dog in it. The mass of the dog and wagon together is 30kg. When she pulls the wagon accelerates at 0.6 m/s². With what force is the girl pulling? (Show all your work)

3. A car with a mass of 1500kg accelerates from a stop at a rate of 4m/s². What force is the engine applying?

4. If the mass of a box is doubled, but it accelerates at the same rate, what is the affect on the force acting on the box? Use data to help explain your answer.

5. If a cart is accelerated at half its original rate (the mass stays the same), how does the force change? Use data to help explain your answer.

6. What is the result of the same force acting on two different objects with different masses?
Force Activity 3

Name: ________________________________

**Objective:** Develop a force law for two objects interacting with each other.

**Pre-Lab:**

Consider a ball resting on top of a table, as shown in the picture to the right.

1. Identify the forces acting on the ball.

2. Draw a force diagram for the ball.

3. What forces are acting on the table?

**Materials:** Two Spring Scales

**Activity:**

***Make sure not to over stretch the spring scales. Do not go above their largest reading.***

1. Take the two spring scales and connect them together.

2. One person holds one spring scale and does not pull. Another person holds the other spring scale and pulls.
   
   A. What observations do you see? What are the readings on the two spring scales?

3. Switch roles. Now the person who was not pulling pulls and the person who was pull does not pull
   
   A. What observations do you see? What are the readings on the two spring scales?
4. Have both people pull on the spring scales at the same time.  
   A. What observations do you see? What are the readings on the two spring scales?

5. With one person pulling on their spring scale, have the other person slowly let their spring scale slide through their fingers. (Be careful not to drop it)  
   A. What observations do you see? What are the readings on the two spring scales?

6. What can you say about the magnitude of forces acting on the two people? What evidence do you have to support this?

7. What can you say about the direction of the forces acting on the two people? Support your claim with evidence.

8. How do you think the forces would compare if instead of pulling they were pushing? Explain your answer.

9. Draw two force diagrams for the situation in which the two people were pulling. One diagram will be for the first person and the other will be for the second person.

10. Draw two force diagrams for the situation in which one person is pulling and the other is just holding the spring scale. One diagram will be for the person pulling and the other will be for the person holding.

11. Compare your force diagrams in questions 9 and 10.
Force Worksheet 3

Name: ________________________________

1. In your own words explain Newton’s Third Law and give an example of it.

2. Can an inanimate object (such as a table) exert a force? Can the magnitude of the force exerted by an inanimate object change? Give an example and explain.

3. When a hammer strikes a nail, how does the force the hammer exerts on the nail compare to the force the nail exerts on the hammer?

4. When you jump, does the Earth move down away from you? Explain.

5. Two of your friends are on roller skates. They start out stationary but you observe Sally push off of Bill. Bill starts accelerating to the right.
   a. What direction would Sally move or would she stay still? Explain why.

   b. If Bill accelerates at twice the rate of Sally, what does that tell you about their relative masses? How do you know?
6. If a bicycle and a semi-truck have a head-on collision, upon which vehicle is the impact force greater?

Which vehicle undergoes the greater change in acceleration? Explain why.