Einstein's Struggles: Molding Students' Early Attitudes Toward STEM Learning by Promoting Curiosity, Observation, and Error.

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This curriculum unit is recommended for:
Fifth-grade science (materials provided in English and Spanish)

Keywords: forces and motion, acceleration, friction, gravity, mass, force, variable, experiment, exploration, science, inertia, law of motion, inercia, ley del movimiento, fuerzas, movimiento, aceleración, fricción, gravedad, masa, fuerza, variable, experimento, exploración, ciencias.

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: This unit is built for teachers and students who are not necessarily comfortable with physics concepts. Some teachers at the elementary level are not sure how to incorporate science in their teaching, since science may not have been an enjoyable or easy subject for them during their early academics. With this in mind, this unit seeks to teach a fifth-grade lesson on forces and motion, using hands-on activities in a structured format for the teacher, yet in a broad, flexible format for the students. Appendix 2 and Appendix 3 contain a unit outline and materials. Appendix 4 contains an annotated bibliography.

I plan to teach this unit during the coming year to **90** students in **fifth-grade STEM Lab** at a **dual-language school.** Classes are conducted solely **in Spanish**.

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Tabitha L. Miller

Rationale

As a student, I was never very interested in science…until I dissected a fetal pig in college. It took until college for me to find an interest in science. I also never felt I was very good at science or "cut out" to find a career in the field, much less study it, other than the required courses for completing a degree. While my background in science is certainly limited, I have found that I have a knack for understanding the concepts, as long as I learn them in a practical, hands-on way. With this in mind, last academic year I accepted a position teaching science at a dual-language immersion school.

Attitudes and experiences like mine are prevalent in modern education, for many reasons. An NPR article recently discussed a study that revealed one interesting reason for the prevalence of these attitudes. In brief, researchers at Columbia University surveyed high-school students, having them write words that described scientists. Eighty to ninety percent of ninth- and tenth-grade students interviewed used the words "genius," "famous," and "research" to describe scientists. During the study, students were exposed to stories about successful scientists who had failed in their work before making important discoveries. Motivation and performance in science coursework were significantly improved among students who read stories about scientists who struggled, as opposed to those who read stories that touted scientists as geniuses.[i] One such "struggle story" was about Einstein's difficulties with a mathematical concept, in which he had to ask Max Planck to help him. In fact, Einstein "claimed that he had no special talents but was passionately curious" (quoted in "habits of mind: curiosity,"[ii]). This story seemed to encourage students to feel more capable in and less threatened by science in academics.

Another set of personal experiences inspired me to build my unit around curiosity and observation. The first CTI meeting for the seminar "How Science is Done" ended with an experiment. Our seminar leader, Dr. Susan Trammell, a professor in UNCC's Department of Physics and Optical Science, took seminar participants to a science lab. There, she had set up three tables with varying tools and objects, and told each group to learn as much about pendulums as possible in a half hour, with the tools they were given. As a "student," I was apprehensive at first, knowing that my background in science is not especially strong. In fact, I was not sure where to begin. I had not performed an experiment in twenty years, and even those experiments were what Dr. Trammell calls "canned."[iii] "Canned" experiments are those that require the ability to follow specific directions in order, but do not really require critical thinking. Nor, in my opinion, do they inspire curiosity and confidence in the student.

Saying that the experience was eye-opening is an understatement. As a "student," I gained more confidence as I worked, realizing that although my peers knew more than I did in certain areas, I knew more than they did in others. On some of our questions, we were equally stumped. However, since there was only one (very broad) guiding question, we were able to come to our own conclusions, and – most importantly – we walked away with many unanswered questions that had come to us while we worked. We continued talking after the activity, simply yearning for more information. This process of pure observation and "play" allowed us the freedom simply to wonder.

A second experience, as a lab assistant in the Physics and Optics Lab at the University of North Carolina at Charlotte, taught me even more about perceptions about research and discovery. Through active participation in a doctoral student's project on laser-assisted drying of small volume biologics, "doing science" was further demystified. I was encouraged by the fact that I, along with teachers just like me, were able to "do science" and I knew that my students would need to know that, too.

As a teacher, I was enlightened as to how I would like to teach my science courses in the coming year. Students in grades K-5 meet with me for forty-five minutes once per six-day rotation. Because of these time constraints, everything I plan must be very carefully structured in order to maximize the time I have to teach. I also try to make sure students have ample opportunity to explore, observe, make mistakes, and formulate questions about the world around them.

The structure for my lessons is thus: Exploration, Explanation, Experimentation. Students will be introduced to a topic with a hands-on activity. They are asked a broad, guiding question and given time to "play." The time given may be one class period, half a period, or even a few minutes, depending on the complexity of the topic. They record observations and questions. Groups share what went right, what went wrong, and what other questions they have. Following the share session, I will present the content to students, relating it to the experiences they had during observation time. I will then pose more focused questions to them that will answer in another, more focused experimentation/observation period.

My unit encompasses this method. One unit will cover four class periods of forty-five minutes each for a fifth-grade lesson in Spanish; however, I will include resources for classes taught in English as well. I believe that this will inspire critical thinking, and curiosity. I also think it will reduce the dread of making a mistake, while inspiring more interest in science and STEM content, once students understand how scientists really make discoveries – that it is not simply natural brilliance, but hard work, endless questioning, and trial and error. Other benefits include more academic communication, leadership, and cooperative learning. Learning – and motivation to learn -- is enhanced by access to real-world questions where students explore, observe, experiment, and start over as many times as necessary. Ultimately, it all begins with curiosity and confidence.

Students have been blogging this academic year. They will blog their experiences at http://clastem.edublogs.org for parents, other students, and other educators to see.

The rationale for this unit is based largely upon my participation in the Summer Research Experience offered by UNCC's Physics and Optics department.[iv] During this two-week experience, six teachers from Charlotte-Mecklenburg Schools served as assistant researchers on two doctorate students' projects. One project centered on damaging porcine liver tissue and photographing the tissue in order to identify regions of damage. The goal for the project is to aid pathologists in identifying cut margins in tumor-removal surgeries for patients with pancreatic cancer.

I participated in the second project, in which we used lasers to dry samples of trehalose (sugar) solution, with proteins inside, until it became a type of glass, surrounding and protecting the proteins. The makeup of trehalose allows the glass to remain in an amorphous state, which ensures that the function of the protein would not change. If the solution were to crystallize, it could change the shape and function of the protein, rendering it unusable for its purpose. The ultimate goal is to protect these proteins and make them transportable and storable at room temperature, so that underdeveloped communities could obtain and use medical diagnostics and therapeutics without the expenses of cryogenic freezing and freeze-drying techniques.

During this process, the teachers were exposed to "real" science. There are many myths about how scientific research and discovery take place. As noted above, many students think of scientists, researchers, and inventors, as geniuses, and do not realize that science is a varied, interdisciplinary field, very often driven by wonder, creativity, and curiosity. The importance of science teaching, then, is paramount. In fact, "The National Science Teacher Association has declared that a scientifically literate person is one who can ask or determine answers to questions derived from their own curiosity about everyday life experiences... Scientific literacy increases many skills that people also commonly use in everyday life, like being able to solve problems creatively, thinking critically, working cooperatively in teams, and using technology effectively."[v]

We learned about the practicality of the Scientific Method that is taught in schools, as opposed to how science really employs the Scientific Method in research and discovery.

Background

Collinswood Language Academy is a full-magnet dual-immersion school, educating students in grades K-8 in Spanish and English. The school's overarching goal is to produce bilingual, biliterate students who are career- and college-ready. It was the first school of its kind in North Carolina, and is a model for other dual-language immersion programs in the Southeast United States. Visitors frequently come to learn about and experience our unique program. Kindergarten students receive ninety percent of their instruction in Spanish and the remaining ten percent in English. Grades 1-8 are instructed half in English and half in Spanish. Collinswood has high performers and skilled teachers: the school consistently meets expected growth goals and has won numerous awards both nationally and internationally.[vi]

This is Collinswood's first year implementing my position, a K-5 STEM Lab teacher and 6th-grade Integrated Science teacher. I teach grades K-5 in Spanish and grade 6 in English. This position was created to support teachers on the English side, who are tasked with Science education (Spanish teachers are in charge of teaching Math and Social Studies). The goal is to enhance what is already being taught in grades K-5 through hands-on activities rich in strategies to encourage STEM learning.

There are a few obstacles to teaching a Science lab. The most significant are time and space. Class sizes in grades K-3 are reasonable: there are 21-24 students in each class, so centers are definitely more feasible. Fourth- and fifth-grade classes have an extra 7-8 students each, since four classes are combined into three total classes. Therefore, these classes have 28-31 students each. This makes organization difficult, since there must be multiples of each station to accommodate groups that are small enough for true exploration and interaction. Language is not an obstacle, since students are, for all intents and purposes, largely fluent in both languages at an early age in the program. Students often speak in "Spanglish," a mixture of the two languages, as they insert words from one language when they do not know them in the other. Having a Spanish-language Science class seems to enhance bilingualism and biliteracy, since students are exposed to the concepts and vocabulary in both languages (their English teachers teach them Science also). Supplies are not generally an obstacle, since all the Science supplies for the entire school are located in my classroom. Technology can be an enhancement and an obstacle, depending on the teacher's planning; however, Collinswood's students in grades 4-8 have Chromebooks, I have a few iPads, and there are Chromebook and iPad carts across the school. Additionally, my school's PTA raises a good deal of money and helps teachers acquire what they need to teach. High parent involvement is also a key component of the success of Collinswood's program. This is a huge help for teachers at my school. A DonorsChoose grant also helped me acquire 3-D printer pens and filaments for my students.

Objectives

By the end of this unit, students will be able to demonstrate their understanding of acceleration of an object. They will create a graph to show their findings. They will learn about friction, mass, weight, force, velocity, and acceleration. Teachers may also include concepts like inertia, Newton's three laws, and potential and kinetic energy. Students are able to deduce and explain many concepts without direct explanation; therefore, a teacher may wish to simply have background knowledge of these concepts in order to answer students' questions or push them further. However, many teachers will want to include these ideas in their direct instruction.

Content Background

Several concepts are necessary for the teacher to know in order to present and facilitate the exploration of concepts in this unit. Teachers will need to know basic definitions, at the fifth-grade level, of the following terms, which are defined in terms students will best understand.

- Friction – a resistance that occurs when two objects are moving in contact with one another.
    - Friction is everywhere and helps us do many things, like walk, hold a pencil, and ride a bicycle.
- Mass – how much matter something contains.
    - Mass is different from weight since a person with 70 kg of matter in his body (mass) could have different weights on other planets, simply because weight depends on gravity, and gravity is different on Earth than other planets.
    - Mass is measured in grams or kilograms for most common objects.
- Weight – tells us how much gravity is pulling down on us and is also based on how much matter we contain.

    - Weight and mass are not the same but are related.
- Force – a push or pull exerted upon an object.
    - Force helps us kick a ball, pull the rope in a game of tug-of-war, and push a door open.
    - Force is measured in a unit called *Newtons*, aptly named for Isaac Newton, whose three laws of motion help us understand the world around us.
- Acceleration – is the relationship between force, mass, and velocity.
    - You can find out how much force is applied to something (like when you kick a ball) by observing how much mass the ball has and how the object accelerates (goes faster).
    - Generally, acceleration is measured in meters per second squared (m/s^2).
- Inertia – this is what makes a person fly off the skateboard when the skateboard hits a rock (see Newton's First Law).
- Newton's First Law of Motion states that an object that is at rest (not in motion) will stay at rest unless someone comes along and applies a force to get it moving. This goes for something in motion: unless someone or something comes along to stop it (maybe friction, perhaps?), the object will stay in motion, pretty much forever!
- Newton's Second Law of Motion states that acceleration happens when a force acts on an object that has mass. If the mass is bigger, a bigger force will be needed to make it accelerate. If it's smaller, not so much force will be needed.
- Newton's Third Law of Motion states that for every action, there is an equal and opposite reaction. Think of someone bouncing a ball on the side of a building. The ball goes forward, hits the wall, and comes back to the person with the same force. It's an equal reaction to them throwing the ball, but an opposite reaction, since it came back the other way.

The same concepts above appear in Spanish below.

- La fricción – la resistencia que ocurre cuando un objeto está moviéndose en contacto con otro objeto.
    - La fricción está en todas partes y nos ayuda a hacer muchísimas cosas, tales como caminar, agarrar un lápiz, y montar una bicicleta.
- La masa – la cantidad de cuánta materia contiene algo
    - La masa es diferente del peso porque alguien con 70 kg de materia (masa) en su cuerpo pesaría diferente en diferentes planetas, sencillamente por el efecto de la gravedad, la cual es diferente en cada planeta.
    - Se mide la masa en gramos y kilogramos para muchos objetos comunes.
- El peso – nos dice cuánto la gravedad nos está atrayendo a la tierra.
    - También se basa en la cantidad de materia que contenemos.
    - El peso y la masa no son la misma cosa, pero se relacionan.
- La fuerza – el proceso de jalar o empujar un objeto
    - La fuerza nos ayuda a patear una pelota, jalar una soga durante un partido de *tug-of-war*, y empujar una puerta para abrirla.
    - Se mide la fuerza en una unidad llamada *Newton*.
- La aceleración – la relación entre la fuerza, la masa, y la velocidad.

    - Puedes averiguar cuánta fuerza se ha aplicado a un objeto (como cuando pateas una pelota) al observar cuánta masa tiene la pelota y cómo se acelera el objeto (el incremento de rapidez).
    - Generalmente, la aceleración se mide en metros por segundo cuadrado (m/s^2).
- La inercia – es la fuerza que hace volar a una persona de una patineta si la patineta se choca con una piedra grande (véase a la primera Ley de Newton).
- La Primera Ley de Movimiento de Newton indica que un objeto que está en reposo (que no está en movimiento) se quedará en reposo a menos que alguien venga y le aplique una fuerza al objeto para moverlo. Esto es igual para los objetos que ya están en movimiento: se quedarán moviéndose siempre, al menos que algo o alguien venga a darles una fuerza para pararlos (la fricción, ¿quizás?).
- La Segunda Ley de Movimiento de Newton indica que la aceleración ocurre cuando una fuerza actúa sobre un objeto que tiene masa. Si la masa es grande, la fuerza también tiene que ser grande para mover el objeto. Si la masa no es tan grande, la fuerza puede ser menos.
- La Tercera Ley de Movimiento de Newton indica que, para cada reacción existe una reacción igual y opuesta. Piensa en alguien que está tirando un baloncesto a una pared de un edificio. Ese baloncesto se encuentra con la pared, y regresa con la misma velocidad, pero en una dirección opuesta. Es una reacción igual porque viene con la misma fuerza que cuando fue tirada, pero opuesta porque vino en la dirección opuesta.

Strategies and Activities

Please see Appendix 2 for student worksheets with guiding but broad questions to lead them through each of the activities below. Since there are around 25-30 students in each class, for each of the exploration centers, there will be multiples of each station.[vii]

Lesson One consists of exploration centers. In each center, students will predict, play, and confirm. In one center, students will push objects on scooter boards across the room or down the hall. In another center, students will put a larger piece of cardboard (or poster) at different angles to the floor and experiment dropping a marble or other objects from the top of the cardboard. They will record their findings. *The objective is for students to explore force, gravity, acceleration, and friction, but not necessarily to know that they are learning those specific concepts. Students are likely to be able to explain how mass and height can affect the motion of objects. Hopefully, students will glean that an object of more mass requires more force (a bigger push) and vice versa. If a student asks a question the teacher is not sure about, an excellent is response is, "Why do* you *think that is?" or "I'd like for you to investigate that excellent question and come back next week with the answer for the class."* It is certainly acceptable for a teacher to say he does not know the answer, but praise the student for advanced thinking.

Lesson Two consists of two more exploration centers, held outside if the weather permits. In one center, students take turns kicking soccer balls from the same starting point. (2) Take turns kicking a soccer ball and a beach ball from the same starting point. *The objective is again for students to learn about force, friction, and mass, but this time they are also doing an experiment with variables. Students should be able to deduce that a harder kick (force) will move the ball farther. They might even talk about how the beach ball is less easy to control when they* *kick it. The idea is to expose students to the first stage of experimentation: observation. It is great fun to watch students explore things, ask their own questions, and come up with their own ideas about how things work. It also helps them develop their linguistic and problem-solving skills, by not yet giving them the words they need to talk about a topic. They have to find ways to explain what they mean.*

Lessons Three and Four are explanation lessons. They begin with a whole-class lesson in which concepts from the previous exploration centers are identified and explained. Key terms are: *force, speed, mass, acceleration, friction, and gravity*. After the whole-group explanation, students work on Chromebooks in groups or individually to complete the skate park simulation at the following site: https://phet.colorado.edu/en/simulation/legacy/energy-skate-park. This site is free for teachers and students and most PHET simulations come with a student guide. The teacher may wish to begin by showing the simulation on the board and walking students through how it works and what they should do. Perhaps the teacher completes the first trial with the students.

Lesson Four (and further option lessons) will include a design challenge. Students tend to enjoy the term “experiment” but this activity might fall under the categories of engineering challenge *and* experiment, since they will be testing their creation. Students will design a car using K’Nex cubes (or any other building blocks or materials). The force will remain the same (a spring scale can be used to “launch” the car); but *mass* will change. Students will only be told the parameters of the challenge, not what to look for or how to manipulate their cars to travel faster. More information follows in the appendix.

Appendix 1

Teaching Standards

The standards used for this unit are taken from the North Carolina Essential Standards for Science, Grades 3-5.[viii] North Carolina's science standards focus on what students will be able to do with the information the learn. The Department of Public Instruction encourages hands-on activities and experiments, driven by inquiry and enhanced by technological design.

In fifth grade, students are expected to make predictions, test those predictions, and deduce some concepts based on the results of their tests. Careful observation and accuracy in record-keeping are important at this age. Students may use more advanced scientific tools, although in this teacher's experience, careful training and close adult supervision are still required. Recognition and examination of patterns in the data they collect, as well as use of more sophisticated language to explain their findings, are both critical at this point in science.

The overarching standard for this unit is:

- **Forces and Motion: 5. P. 1:** Understand force, motion and the relationship between them.
- While our focus in this unit is 5.P.1.3 and 5.P.1.4, students will also learn about gravity, friction, and distance, which are included in standards 5.P.1.1 and 5.P.1.2.
    - According to the North Carolina Essential Standards, students should know that gravity is a force that pulls an object toward the earth. It is an invisible, intangible force, and it works differently on different planets. The bigger the object, the more gravity it exerts on other objects (so smaller planets exert less gravity).
    - An excellent way to show how gravity works is through any of the hundreds of videos NASA has produced showing a day in the life of an astronaut. Students get to talk about what life must be like in lower gravity and how a person can weigh less in space, but remain the same size (they never seem to have shrunk when we see them in the video!).
    - For younger students (K-1), I ask them to float in the air like an astronaut does on the moon. They jump up, and land feet first. I tell them again, "Okay, this time, we're really going to float. Try to stay up in the air." They jump again, and we giggle. Finally, I act as if I have simply given up on them. We all laugh and they try to explain to me why they cannot float. We talk about an invisible force that pulls us down toward the earth and will not let us float, and we follow that with a video showing an astronaut not feeling that same pull of gravity in space.
    - Students will also understand that friction is all around us and helps us in our everyday lives. There are good and bad results of friction. They will want to know about friction in order to understand how to design their cars.

The two specific objectives that are covered in this unit are:

- **5.P.1.3:** Illustrate the motion of an object using a graph to show a change in position over a period of time.
    - When students are in the exploration and experimentation stages, they will be keeping records of how objects move. They may graph, draw, or describe verbally or in writing, their observations.

- **5.P.1.4:** Predict the effect of a given force or a change in mass on the motion of an object.
    - Students should know that the greater a force is, the greater a change in motion is produced. They should also be aware that the bigger an object is (the more mass it has), the more force will be needed to move it.

Appendix 2

Unit Outline

<table>
<tr><td colspan="6"></td></tr>
<tr><td>Grade</td><td>5</td><td>Month</td><td>October-November</td><td># of Meetings</td><td>3-6</td></tr>
<tr><td>Topics and Objectives</td><td colspan="5">Forces and Motion
5.P.1.3: Illustrate the motion of an object using a graph to show a change in position over a period of time.
5.P.1.4: Predict the effect of a given force or a change in mass on the motion of an object.</td></tr>
<tr><td>Lessons</td><td colspan="5">Lesson 1: Exploration centers. (1) Push objects on scooter boards across room or down hall
(2) Drop marble from top of a piece of cardboard (or poster) from a larger box. Tilt the box at different angles and record times.

Lesson 2: Exploration centers outside. (1) Take turns kicking soccer balls from same starting point. (2) Take turns kicking a soccer ball and a beach ball from the same starting point.

Lessons 3 and 4: Explanation. (1) Whole-class: Key terms: force, speed, mass, acceleration, friction. (2) Group or individual on Chromebooks: https://phet.colorado.edu/en/simulation/legacy/energy-skate-park.

Lesson 5: Design a car using K’Nex cubes (or any other building blocks or materials). The force will remain the same (a spring scale can be used to “launch” the car); but mass will change.

Extend engineering session if necessary so that students have time to plan, test, and race their cars.</td></tr>
<tr><td>Extension</td><td colspan="5">(1) Make marshmallow shooters; (2) design boats and float them; (3) design and/or build a roller coaster; (4) build a spoon catapult.</td></tr>
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Appendix 3

Lesson Plans and Materials

Lesson 1: Exploration centers.

Objectives: Students will freely explore with materials in two centers. Students will explore how different levels of force make objects move in different ways. Students will explore how gravity and height affect kinetic energy.

Center 1 materials: scooter boards from the school's P.E. program; books or other objects that students can put on the scooter board.
Center 1 directions (cut out and place near center materials):

CENTER 1: SCOOTER BOARD

Use the materials present to answer these questions:

1. How does it move when lighter objects are on it?
2. How does it move with heavier objects on it?
3. What causes it to stop or slow down?
4. What do you already know that may explain your observations?

CENTRO 1: El ESCÚTER

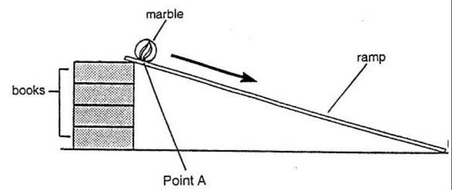
Utilicen los materiales presentes para contestar las siguientes preguntas:

1. ¿Cómo se mueve con objetos ligeros encima?
2. ¿Cómo se mueve con objetos pesados encima?
3. ¿Qué causa que el escúter se pare o se vaya más lento?
4. ¿Qué ya saben que les puede ayudar a explicar sus observaciones?

Center 2 materials: marbles; large piece of cardboard or long, thin wooden block if available; protractor if available; pencil and paper to record observations; stopwatch; books to raise the ramp height.

CENTRO 2: RAMPAS

Utilicen los materiales presentes para contestar las siguientes preguntas:



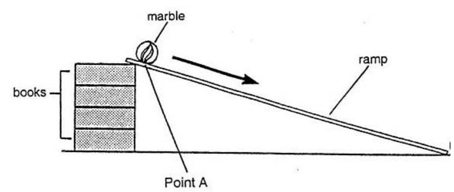
1. ¿Cómo se mueve la canica cuando la rampa tiene más altura?

2. ¿Cómo se mueve la canica cuando la rama es más baja?

3. ¿Qué ya saben que les puede ayudar a explicar sus observaciones?

CENTER 2: RAMPS

Use the materials present to answer these questions:



1. How does the marble move when the ramp is higher?

2. How does it move when the ramp is lower?

3. What do you already know that may explain your observations?

Lesson 2: Exploration centers outside.

Objectives: Students will use given materials to explore how force is used to make objects move different distances. Students will explore how the mass of an object and the force applied both affect its movement.

Center 1 materials: soccer ball; tape measure; yardsticks; stopwatches.

CENTER 1: SOCCER

Use the materials present to answer these questions:

1. How does the ball move, based on different kicks?

2. What causes it to stop or slow down?

3. What do you already know that may explain your observations?

CENTRO 1: FÚTBOL

Utilice los materiales presentes para contestar las siguientes preguntas:

1. ¿Cómo pueden afectar el movimiento las patadas diferentes?

2. ¿Por qué se para o se va más lento el balón?

3. ¿Qué ya saben que les puede ayudar a explicar sus observaciones?

Center 2 materials: soccer ball; tape measure; stopwatches; yardsticks; beach ball. (Students could also roll a softball, golf ball; Styrofoam ball, and ping pong ball at this station.)

CENTER 2: SOCCER

Use the materials present to answer these questions:

1. Does the size or weight of the ball affect its movement?

2. What do you know that may help you explain this?

CENTRO 2: FÚTBOL

Utilice los materiales presentes para contestar las siguientes preguntas:

1. ¿Cómo afecta el movimiento el peso del balón?

2. ¿Qué ya saben que les puede ayudar a explicar sus observaciones?

Lessons 3 and 4: Explanation and experimentation.

Objectives: Students will discuss their observations in the previous class periods. Students will acquire and use key academic terms about forces and motion. Students will perform a virtual lab about forces and motion.

Lesson 3: Use the editable PowerPoint presentation (English: http://bit.ly/2g9m09N and Spanish: http://bit.ly/2g8Wkd7) to teach students concepts about forces and motion. Students begin by discussing what they observed *without using academic language*. After the presentation, they are asked to write about one or more of the concepts and how they observed them in their exploration centers.

Lesson 4: Students use Chromebooks (either in groups or individually) to perform the virtual lab located at https://phet.colorado.edu/en/simulation/legacy/energy-skate-park . The website has many other PHETs to choose from, along with materials to offer students as guides, if the teacher prefers. If no devices are available, the teacher can display this on the Smartboard or using a projector, and the class can complete the lab together.

Lesson 5 (and perhaps 6): Experimentation and engineering.

Objectives: Students will plan, design, and test a product that will illustrate their understanding of basic concepts of forces and motion.

Have students design a car using K'Nex cubes (or any other building blocks or materials). The force will remain the same (a spring scale can be used to "launch" the car); but *mass* will change.

Extend engineering session if necessary so that students have time to plan, test, and race their cars.

Have each group use the following engineering planning sheet:

Names: ____

How will you make a fast-moving car? Every group will use the same force to launch their cars. We will pull back a rubber band the same distance and launch our cars. Based on what you've learned, how will you design your car so it will move the fastest?

(1) Make a plan. Discuss, sketch, and write.

(a) What materials will you use?

(b) How big/small will your car be?

(c) Who will do what?

(2) Test your car. Your teacher will demonstrate how far the rubber band should be pulled back. Use the results table in your testing.

Trial Run Number	How far your car traveled (in centimeters)	How much time before it stopped (in seconds)
1		
2		
3		

Compare your results with another group's results.

(3) Re-design your car. You have one chance to make your car faster. What will you change?

(4) Re-test your car. Fill in the results.

Trial Run Number	How far your car traveled (in centimeters)	How much time before it stopped (in seconds)
1		
2		
3		

(5) After the whole-class test, what did you learn about your design? What did other cars have that yours did not? What factors affected how your car moved?

Nombres: ____

¿Cómo crearán un carro que viaja rápidamente? Cada grupo usará la misma fuerza para empujar su carrito. Jalaremos un elástico la misma distancia para empujar los carritos. Basándose en lo que han aprendido, ¿cómo diseñarán su carro para que se mueva más rápidamente que los demás?

(1) Hagan un plan. Discutan, dibujen, y escriban.

(a) ¿Cuáles materiales utilizarán?

(b) Cuán grande o pequeño será tu carrito?

(c) ¿Quién hará qué?

(2) Ensayen su carrito. Su maestro(a) demostrará cuán lejos tiene que ser el elástico. Utilicen la tabla para grabar los resultados de las pruebas.

Número de la prueba	La distancia que viajó su carrito (en centímetros)	Cuánto tiempo viajó su carro (en segundos)
1		
2		
3		

Compare sus resultados con los de otro grupo.

(3) Diseñen su carro de nuevo (o cámbienlo). Tienen una oportunidad para mejorarlo. ¿Qué cambiarán?

(4) Ensayen su carrito de nuevo. Llenen los resultados.

Número de la prueba	La distancia que viajó su carrito (en centímetros)	Cuánto tiempo viajó su carro (en segundos)
1		
2		
3		

(5) Después del ensayo de toda la clase, ¿qué aprendieron sobre su diseño? ¿Qué tenían los demás carros que no tenía el suyo? ¿Cuáles factores afectaron el movimiento del carro?

Appendix 4

Annotated Bibliography

Please find below some excellent resources for planning your science curriculum for elementary and middle school.

Eichinger, John. *Activities Linking Science with Math, K-4*. Arlington, VA: NSTA Press, 2009.

> Many districts and schools are incorporating the STEM or STEAM model into their Elementary programs. This requires STEM-lab teachers to incorporate math, engineering, technology, and even art into their units of study. This text assists teachers in linking science concepts with math without having to shoe-horn those concepts in just to make an administrator or district official happy. These additions to the science curriculum make sense and work well.

Keeley, Page. *Science Formative Assessment. 50 New Strategies for Linking Assessment, Instruction, and Learning*. Thousand Oaks, CA: Corwin, 2015.

> This second installment of the assessment series is a great addition to the first volume (see below). It is a virtual treasure trove of resources for teachers, and can be used in any academic discipline.

Keeley, Page. *Science Formative Assessment: 75 Practical Strategies for Linking Assessment, Instruction, and Learning*. Thousand Oaks, CA: Corwin Press, 2008.

> This research-based text offers teachers well-supported assessment techniques and activities that activate prior knowledge, engage students, encourage discussion, promote scientific inquiry, provide for reflection, and allow students to assess themselves and one another. The text is well-organized and detailed information helps teachers understand what they assess, why they use a particular assessment, and how to modify teaching with the data they collect from an assessment.

Keeley, Page, and Rand Harrington. *Uncovering Student Ideas in Physical Science: 45 New Force and Motion Assessment Probes*. Arlington, VA: NSTA Press, 2010.

> This text is another excellent resource for science teachers. Some teachers find that teaching forces and motion to younger students can be more challenging than other topics. This book focuses on teaching forces and motion to elementary-aged students, and the activities can easily be adapted to younger or older grades.

Lin-Siegler, Xiaodong, Janet N. Ahn, Jondou Chen, Fu-Fen Anny Fang, and Myra Luna-Lucero. "Even Einstein Struggled: Effects of Learning about Great Scientists' Struggles on High School Students' Motivation to Learn Science." *Journal of Educational Psychology* 108, no. 3 (2016): 314-28. doi:10.1037/edu0000092.

A study was performed among more than 400 ninth- and tenth-grade students to find out what students' attitudes were about science and scientists of fame. The study showed that students who read stories about scientists who struggled were more likely to perform better and be more motivated in their study of science.

Robertson, William C. *Companion Classroom Activities for Stop Faking It!: Force & Motion*. Arlington, VA: NSTA Press, 2011.

Any teacher who is the least bit uncomfortable in their abilities in teaching physics should take a look at this book, since it offers several easy-to-implement activities to teach forces and motion. Obtaining a copy of the book for which this one is a companion is also recommended.

Sawah, Rihab. *The Everything STEM Handbook: Help Your Child Learn and Succeed in the Fields of Science, Technology, Engineering, and Math*. Avon, MA: Adams Media, 2015.

This book is a quick-reference handbook full of ideas for STEM activities. It offers a great deal of information about each activity, experiment, or challenge.

"STANDARD COURSE OF STUDY." Science. Accessed November 01, 2016. http://www.dpi.state.nc.us/curriculum/science/scos/support-tools/.

All Essential Standards for science instruction are listed here, by grade level.

Yager, Robert Eugene. *Exemplary Science in Grades 5-8: Standards-based Success Stories*. Arlington, VA: NSTA Press, 2006.

This book is a both an in-depth treatment of incorporating the National Science Education Standards (NSES) into teaching. At the time of this writing, Charlotte-Mecklenburg Schools' science teachers use the North Carolina Essential Standards to guide their science teaching; however, many states have adopted the Next Generation Science Standards (NGSS). All of these sets of standards have similarities and all have value for science teachers. The value of the book, however, is not in the use of a particular set of standards, but how to implement those standards effectively. One essential chapter is "Chapter 7: *More Emphasis* on Scientific Explanation: Developing Conceptual Understanding and Science Literacy." This chapter explains the new shift to the CER (Claim, Evidence, Reasoning) method of explaining one's findings, as opposed to the unyielding Scientific Method model.

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[i] Vedantam, Shankar. "How Stories Told of Brilliant Scientists Affect Kids' Interest In The Field." Hidden Brain A CONVERSATION ABOUT LIFE'S UNSEEN PATTERNS. June 07, 2016. Accessed November 01, 2016.

http://www.npr.org/2016/06/07/481058613/how-the-stories-told-of-brilliant-scientists-affect-kids-interest-in-the-field and Lin-Siegler, Xiaodong, Janet N. Ahn, Jondou Chen, Fu-Fen Anny Fang, and Myra Luna-Lucero. "Even Einstein Struggled: Effects of Learning about Great Scientists' Struggles on High School Students' Motivation to Learn Science." *Journal of Educational Psychology* 108, no. 3 (2016): 314-28. doi:10.1037/edu0000092.

[ii] The text "habits of mind" is excerpted from the Framework for Success in Postsecondary Writing, a guide published in January of 2011 by by the Council of Writing Program Administrators (CWPA), the National Council of Teachers of English (NCTE), and the National Writing Project (NWP).

[iii] Trammell, Susan. CTI Seminar Discussion. May 05, 2016.

[iv] Find more information about the Science Research Experience at http://charlotteteachers.org/wp-content/uploads/2016/09/Science-Research-Experience.pdf.

[v] Ackay, Hakan, and Robert E. Yager. "Students Learning to Use the Skills Used by Practicing Scientists." Eurasia Journal of Mathematics, Science & Technology Education 12, no. 3 (January 06, 2016): 513-25. January 06, 2016. Accessed November 1, 2016. file:///C:/Users/tabit/Downloads/eurasia_2015_1395a (3).pdf.

[vi] "About Our School." Accessed November 1, 2016. http://schools.cms.k12.nc.us/collinswoodMS/Pages/AboutOurSchool.aspx.

[vii] I recommend giving students fewer stations if the activity is somewhat complex or requires a lot of discussion and critical thinking. Multiples of each station (3 each of two stations) provides for smaller groups, more hands-on activity for each student, and easier discussion among students.

[viii] "North Carolina Essential Standards 3-5 Science." Accessed November 1, 2016. http://www.dpi.state.nc.us/docs/curriculum/science/scos/support-tools/new-standards/science/3-5.pdf.