Avoiding Cookie Cutter Science with Gifted Children by Moving Students through the Inquiry Process

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This curriculum unit is recommended for:
Elementary Grades Three, Four and Five – Science, Force and Motion

Keywords: Force and Motion, Physics, Newton's Laws of Motion, Infographics, Inquiry, Science, Laboratory, Science Fair, Elementary School, Friction, Graphing

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

Synopsis:

The focus of this unit is on Inquiry investigations as opposed to the traditional, found in a textbook, "Cookie Cutter" recipe type science. Traditional textbook investigations usually tell the students exactly what to do (procedure) and often even what to expect will happen. Students do not have to worry about controlling variables, because the variables are already controlled within the design of the investigation. Because the steps of the investigation are spelled out in the science textbook, students do not learn how to set up activities in which they think critically about variables and controls and as a result the creation of a Science Fair project is met with great frustration. In this unit, the teacher will actively instruct the students in inquiry, gradually releasing the control of the design and implementation over to the students. As a result, the students will be expected to learn how real science works and will be expected to design a good inquiry investigation on their own, hopefully resulting in quality Science Fair projects and engaged student-scientists.

I plan to teach this unit during the coming year to 31 students in grades three and four, during their Science blocks.

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Introduction

When looking at the science our students experience in the school setting we rarely see anything that relates to or mirrors "real-world science". Teachers are guilty of giving prescribed, cookie cutter procedures and expecting the students to follow these to end up at an 'expected discovery'. We do our students a disservice in portraying this cookie cutter lab experience as the way real science is undertaken; at the very least, we stymie any curiosity the students have by essentially telling them that they will see "this result" happen. We leave no room for the unexpected or for pure discovery.

Within this curriculum unit it is my desire to take my students from what most of them have always known in school (cookie cutter science) to self-directed inquiry, by progressively releasing more of the decision making and direction to the student.

According to the National Science Education Standards, inquiry instruction involves students in a form of active learning that emphasizes questioning, data analysis and critical thinking.[1] The importance of inquiry in science instruction is reiterated by Karen Ostlund when describing the process of scaffolding students into inquiry:

> Moving from teacher-directed to teacher-facilitated to student-directed inquiries allows for a continuously deepening understanding of the skills and knowledge fundamental to conducting inquiry.[2]

Rationale

The "red flag" in the classroom, which lead me to developing this unit, is that students are presented with the task of creating a "Science Fair" project beginning in third grade. Over the years I have seen students really struggle with developing true inquiry projects, instead they try to copy a "science recipe" off of the internet. Additionally, those who do come up with their own ideas and projects will change multiple components of their procedures at one time, changing several variables instead of changing one variable only, because the students do not really understand inquiry.

I believe that when students really understand the inquiry process and what is involved in designing a good science investigation, then the issue we see with uncontrolled and multiple variables will disappear, leaving us with student-scientists who truly understand the "how" of "doing science". Thus, this need for inquiry understanding on the part of the students is what drives this unit.

School & Student Background

I teach a third-fourth grade combination class at an elementary school comprised of 602 students. My school is very unique, in that we have four separate programs making up our overall student population. Our school consists of extremely high performing students (the Horizons program), academically gifted students (our Talent Development -- TD program), classes for K-2 students who have shown potential to be in our TD program (the Learning Immersion students), and our "Academy" students who come largely from our surrounding neighborhood. We are also a "Title One" school, which means that at least 75% of our student population is at poverty level. Our school racial makeup is very diverse: 56% African-American, 21% Asian, 4% Hispanic, 16% White and 3% other. Integral to our school is our high level of parent involvement, especially within our Horizon's and TD programs.

Although for many years I taught a Talent Development class, where all students in the class had been identified as "Academically and Intellectually Gifted", this year I am teaching the Horizons students. The Horizons program consists of extremely high performing, gifted students. These students are oftentimes anywhere from two to four years ahead of their peers academically. My current class consists of six third graders and three fourths graders. Barringer is also a Personalized Learning school. This is a component of our school that threads throughout all of our programs. Students and teachers work together to design an instructional path that not only focuses on the students' academic needs but also allows for their interests and strengths to come into consideration. My classroom is a "One-to-One" technology class; all of my students are provided a Chrome Book to use in the classroom. I am responsible for teaching all subjects to my students, including Science and Social Studies. My students typically will receive 2-3 days of Science instruction a week, for about sixty to ninety minutes each day. They will also work on their ongoing science work when time allows on other days.

The fact that I work with and instruct gifted students is central to this unit. Although I believe any student in any science classroom can benefit from this shift to student directed discovery, within the gifted classroom this is especially important. As stated by Estes and Dettloff, "For gifted students, the pace of the (teacher directed) instruction may move far too slowly,"[3] and will result in these students' creativity and curiosity of difficult concepts to be squelched. In addition within my classroom and in working with this population of students, I see a pronounced lack of desire and ability to persevere when they come to a challenge that they cannot solve immediately (i.e., open ended un-scripted science or math). Gifted students especially, tend to be perfectionistic[4] and self-critical when they lack understanding or expertise. They need to be taught within a classroom culture that reflects the growth mindset – where failing and frustration are roads to success.[5] Indeed, research has shown that growth in the brain actually occurs with challenge and struggle.[6] Within this inquiry model, there is a gradual transfer of ownership of the science activities over to the student, which forces the students to face frustrations and struggles head on. The more that they are expected to work within that area of the unknown with support from the teacher, the more they will grow as students who meet problems with confidence. It is our job as teachers of gifted children, to help them build skills where they will keep on trying, risking failure, and pushing through this confusion, frustration and the unknown.

Objectives

This unit is designed to be taught in a somewhat cyclical fashion, progressing students through the stages of inquiry for each science unit, with scaffolding that decreases as the students are given more and more ownership of their investigations. The processes and procedures will be introduced in the first weeks of school but reviewed through application of these procedures throughout the school year. After a brief introduction to what a scientist does in the real world, the students will begin moving through mastery of a true-inquiry process, by way of lessening instruction and scaffolding by myself, their teacher.

The science focus of this unit will be force and motion, specifically as it covers Newton's three laws of motion. This is the focus of force and motion in the third and fifth grades in North Carolina, although the strand of force and motion penetrates science at every elementary grade level. Within these two grades the emphasis is on motion and what affects an object's motion (first law of motion), and also on velocity and acceleration (second law of motion).

In addition to this science focus, this unit will include Language Arts, especially in the area of informational writing, the arts (scientific poster or infographic construction), Mathematics (use of formulas and graphing of results) and Technology. (For full delineation of teaching standards, please see Appendix 1.)

Content Background and Research

In general, students struggle with the scientific process, in part because teachers have taught it from a "closed model" viewpoint. In almost any elementary classroom that teaches some science, you will see a poster that delineates the "Scientific Method"; the poster almost always implies that when the sequence of steps reaches the conclusion point that the investigation is over and closed. We teach the "scientific method" as if all the science conducted in the real world is like this process. In reality, real science is not like that, but is instead a continually evolving process that changes over time, where one 'answer' or conclusion almost always prompts more questions. Real science does utilize a standard way of approaching investigations, an organized method that lends itself to being repeatable by the investigator as well as by other scientists. However real science gives freedom to explore beyond and outside of those "prescribed steps", when the results dictate, taking various tangents to deepen the understanding and discovery.

We must allow our students to spend time observing and recording their observations since much in the science world requires this skill. A significant discovery can come by accident, and must be recognized as important by continued observations (i.e. the discovery of penicillin), and then subsequent controlled and organized investigations. When we consider all of the various disciplines of science and think of the real work being done, we see many different ways and methodologies of exploration and discovery. Examples of these disciplines include medical discoveries, astronomy studies and paleontology, to name just a few.

It is because of this variance within the disciplines that we need to expose our students to different types of science. It is also important that we do not impose our specific ways of attacking a science question upon them. Every question dictates its own manner of investigation. Page Keeley says, “Science is guided by the question(s) posed.”[7] We want our students to be able to investigate their areas of interest in a smart-science manner; thus, the reason for this unit on inquiry.

For the purposes of this paper we will define what we mean when we refer to “inquiry science”. The National Research Council’s (NRC) essential features of inquiry, state that students are doing inquiry when they:

- Are engaged with scientifically oriented questions
- Give priority to evidence
- Formulate evidence-based explanations
- Compare and evaluate the merit of explanations
- Communicate and justify explanations[8]

Additionally, Bell et al. state that inquiry must include a research question and must involve students in analyzing data, whether the data is their own or is compiled data from others or published.[9]

In several publications[9,10] inquiry is broken up into levels that are based on the amount of ownership and complexity expected of the student. These are the general levels:
Level 1 – Teacher gives question, teacher gives methods, and the teacher implies expected result
Level 2 – Teacher gives question, teacher gives methods, and results are open
Level 3 – Teacher gives question, the method is left up to student and results are open
Level 4 – wide open

Breaking this down, the first level is similar to the laboratory activities found in most elementary science textbooks. This is what is referred here in this unit as “cookie cutter” science. The students are given the question, the steps for the procedure and there is one correct outcome. In the second level the students are still given a question and a procedure. According to Bell et al, a level one lesson can become a Level 2 lesson by placing the activity before the content introduction instead of after. [11] Level 3 still has the teacher dictating the question, but the students are allowed to investigate the question with their own methods and resulting outcomes. The full inquiry or Level 4 gives the most freedom to the student to come up with the question, process and procedure and of course results. Levels 3 and 4 require the students to design all activities. Additionally, these activities have appropriately controlled variables within them.

Within the template for open inquiry articles the authors describe a format for guiding students into a process for designing and carrying out their own research within the classroom.[12,13] This process helps to keep the student cognitive of their variables – both independent and dependent variables. The goal within this curriculum unit is to scaffold students through the levels of inquiry with varying amounts of information given to the students at varying levels of complexity.

The content focus will be the instructional standards that relate to Newton’s laws of motion, including standards in mathematics of measurement and data, as well as literacy standards specific to writing and infographics. The production of an infographic covering the content will be the final activity that demonstrates the students' understanding. Infographics present the students with a vehicle for organization and display of their understanding. The students will have a choice of doing this on a standard poster board or of doing it by way of Technology, through either Google Drawings or Canva.com.

One of the issues that students struggle with is identifying and controlling variables. Teachers need to specifically instruct students, giving them plenty of opportunities to distinguish between types of variables. In general, a *variable* is a condition that can exist or be manipulated within an activity. The *control* in an activity is the part that does not get changed by the student, nor is it changed as a result of the activity at hand. There are two types of variables, independent and dependent. The dependent variable is the result or what is observed to happen as a result of the change of the independent variable. An *independent variable* is determined within the activity design and is the one the student will change and manipulate. These independent variables must be watched carefully so that no more than one at a time is introduced or changed. For instance, in an activity which tests the slope of a ramp verses the speed of a ball rolled down this ramp, the student could change the slope or change the mass of the ball, but should not change both at one time. Doing so would give results, which could not be linked to either of the variables.

Students can be reminded continually when doing activates about variables. For instance, when finishing up an experiment where the students investigated the number of drops of water that a penny can hold, the teacher could then go through a series of questions asking the students to think of other ways to test within this system (i.e., changing the coin used, changing the size of the dropper, changing the liquid used), making sure to continually come back to the point of changing only one of these at a time ("could we change the coin to a quarter as well as changing the dropper size?")

Within the elementary classroom and especially in regards to the North Carolina Essential Science standards, the topic of "Force and Motion" is usually centered on the study of Isaac Newton's three laws of motion. These laws of motion are:

1. First Law -- An object at rest will stay at rest unless acted on by an unbalanced force (i.e., something pushes it, hits it or acts on it in some way). Additionally, an object in motion continues to be in motion with the same speed and in the same direction unless acted on by an unbalanced force.
2. Second law -- Acceleration is produced when a force acts on an object (referred to as "a mass"). The greater the mass (of the object being accelerated) the greater the amount of force needed (to accelerate the object). We tend to use a common equation here:

   $$F = ma$$

   where "F" stands for amount of force, "m" stands for the mass of the object and "a" stands for the acceleration.
3. Third law – For every action there is an equal and opposite re-action.

Specifically, the first law, called the law of inertia, is probably the easiest for the students to understand since in its simplest form, they experience this while driving in vehicles with their parents. When a car is traveling, they and the car are in motion. When the car stops suddenly, the passengers (our students) keep moving. Moreover, they continue to move within the car until their seat belt "acts" upon them to restrain their movement. The reverse of this can also be explained with automobile travel. When sitting in the vehicle if their parent "floors it", pressing on the accelerator in a way to cause the car to go fast from their stop very quickly, the student is pushed back into the seat of the car because their bodies are trying to stay at rest.

The second law of motion, which deals with speed, velocity and acceleration, tends to be the hardest to get students to understand. Even just speed, which we would think to be easy to understand, is made up of average speed and also instantaneous speed. For the purposes of our activities in the classroom, we deal with average speed, although students should understand the difference. Speed by definition is the distance traveled or moved, divided by the time it took to go that distance ($s = t/d$). Again this is an average. Students who travel by bus to school can appreciate the fact that their bus driver may go a "speed" of thirty miles per hour, but they know that there are many times the bus is sitting still (speed of zero) while other students get on board. If they know the distance to their house to be twenty miles and the "speed" of the bus to be thirty miles per hour, then technically they should arrive home after forty minutes – but of course they don't; all the stopping probably adds on at least another ten minutes. The instantaneous speed when stopped is zero miles per hour and the instantaneous speed when passing a car may be forty miles per hour.

Most students and many teachers struggle with the term velocity. By definition, velocity is the speed and direction something is moving in. So if the bus is going thirty miles per hour (its speed) and it is travelling west, then its velocity is "30 mph west". When we teach velocity, teaching it with a large "V" and pointing out the two "arms" of the V will help students to remember that it has two components – speed and direction. The fact that it has two components, makes it a "vector" – something that has both magnitude (size or measurement, in this case its speed) and direction.

Acceleration is the change in the velocity of something. Acceleration is confusing because we tend to think of it only in regards to accelerating in our cars. Acceleration can actually be a positive change or a negative change. For example, when we slow down we are actually still accelerating (by definition). Since motion can also have a direction component (think: velocity), then acceleration can happen when the speed remains constant but the direction changes. Because the term acceleration has such a strong connotation, we should give our students ample examples of acceleration occurring when speed decreases or when directions change.

For the purposes of this unit, Newton's third law of motion will not specifically be included, but in a way wraps itself around the other two laws. The third law of motion says that for every action on an object there is an equal and opposite reaction. Within the classroom, the typical activity that demonstrates this in its simplest form is to push on the corner of the wall or a cabinet. If you push hard (the action), you end up with a small dent or impression in the palm of your hand from the wall or cabinet "pushing" against you.

A review of some of the important vocabulary for the teacher and student to understand:

- Inertia – The tendency of an object to remain where it is or continue moving in a straight line at the same speed.
- Force – a push or a pull on an object that causes movement

- Friction – the force between two objects when they are moved against each other. Friction usually produces heat.
- Speed – How fast an object is moving, ON AVERAGE, during a portion of time. Speed is expressed as d/t=s, or the distance moved divided by the time it takes to go that distance, equals speed – how fast an object is moving, again on average.
- Velocity – the speed and direction an object is moving.
- Acceleration – a change in the direction an object is moving or a change in the speed an object is traveling. The 'change' can be positive or negative. Therefore when an object slows down, technically it is 'accelerating', although some science books actually use the term 'deceleration'.

Instructional Implementation - Teaching Strategies and Activities

The activities that follow (Activity #1-4), should be completed over four full Science periods, with time added in for introduction and review of the content and background understanding. Activity 5 (the open inquiry) could take the students as many as three or four days, depending on their focus and understanding of investigational design. Additionally, the last activity (Activity #6, the preparation of the infographic) may take the students two to four class periods. Teachers who wish to do this unit as written, should allow for a total of between nine and twelve class periods, which in my classroom equates to approximately four weeks.

For reference, the terminology used here for stages of inquiry is as follows: Level 1 - "Cookie Cutter" Recipe, Level 2 – Structured Inquiry, Level 3 – Guided Inquiry, Level 4 – Open Inquiry.

The goal is to give students exposure to all levels of inquiry, however this does not have to be in sequence from "least inquiry" to "most inquiry". Often in the context of instruction it might be more effective and valuable for the students to begin a unit with structured and guided inquiry rather than the very basic level of no inquiry. Because of this, the student activities listed here do not follow a prescribed order of increasing complexity, instead levels two and three are flipped for reasons given.

It is also important to realize that these activities are designed to help students come to an understanding of the principles that are included with motion – when a force is exerted, motion results. When the change of position (distance) of that motion is measured, as well as the time elapsed, and these two measurements are put into our formula (s=d/t), then we have the average speed. Activity 1 uses a prescribed procedure to determine average speed. Activities 2, 3 and 4 have varying levels of inquiry, and still measure average speed, but do so with the added component of the force of gravity upon the motion. Because of the force of gravity, the ramp causes the ball to actually be accelerating (the velocity is increasing). Since gravity increases an object's velocity by 9.8 meters per second per second, the resulting average speed with each increase in ramp height should be greater.

Activity 1 – "Cookie Cutter" Recipe

In attempting to focus on inquiry in the science classroom, teachers should only include the classic "Cookie Cutter" recipe activity for specific purposes. In this unit the first activity listed here is a “Cookie Cutter” recipe activity, with the intended purpose of exposing the students to the formula and the tools that will be used in later activities.

Materials needed:

- Stopwatch
- Yard or Meter sticks
- Sidewalk chalk to mark off distance

Procedure:

The students should be instructed in the use of a stopwatch and how to read the time result. If stopwatches are not available, most cell phones have a stopwatch as an included tool (and most students have a phone in their backpack, even at the elementary level!). If neither of these are available, the students can be instructed in how to count off seconds, using the “one-Mississippi, two-Mississippi, three-Mississippi” count. This is surprisingly accurate as long as the same person does the counting.

The students should also be taught how to use the yard or meter stick to measure off longer distances. (Specifically for this activity, they will measure off 10 meters or 10 yards). It is the specific skills of stopwatch timing and measuring with yard sticks that prompts conducting this initial “Cookie Cutter” activity.

Once the students have had practice measuring and timing elapsed time, they will go outside and measure off their “track”. They should mark their beginning and ending place on a sidewalk with chalk. The distance is not critical, but longer distances will give them more consistent times within their trials. I have found around 10 meters (or about 30 feet) to be a good distance for elementary students. They can speed walk their track 3 or 4 successive times, generating 3 or 4 times and then they will average these for their specific time. Their partner should do the same.

When they return to the classroom, they should be instructed to set up an organized table for their data. They will also need instruction in how to use the formula for average speed, $s = d / t$. They should then be asked to create a bar diagram that includes their speed and their partners speed. Instruction should be given on creating a bar diagram, if this has not already been covered in class. Even if the process has been covered in other grades, it is important to review the steps to actually create a graph, not only the reading of graphs. Students should be instructed in determining which portion of the investigation is represented on which axis of the graph. In general, the independent variable is the one which should go on the axis that the bar portion of the graph is anchored to (usually the “x” axis, or the horizontal line). In this investigation the independent variable is the ramp height and that should be represented across the horizontal “x” axis. The dependent variable (the one you measure or determine from your measurements – in this case the speed) will be the scale represented on the “y” or vertical axis. (Please see Appendix 3 for a student example of the data table and bar graph for this investigation).

Remember, this activity is prescribed in this manner to educate the students in the skills of measuring, and timing an activity. The process also results in the students using the formula for average speed, as well as constructing bar graphs; they will use these skills in the subsequent activities.

Activity 2– Guided Inquiry

This second activity is organized at a "guided inquiry" level[14] meaning that the students will attempt to answer the teacher-given question, without specific prescribed procedures. If activity 1 above is conducted then the students are familiar with the formula for speed (or possibly from their Math instruction).

Materials (to be laid out around the room):

- Balls of various sizes, densities and composition (I usually offer a collection of balls made up of marbles, ping pong balls, golf balls, Styrofoam balls, wooden balls)
- "Ramp" materials offered include: lengths of shelving board, hot wheel tracks of various lengths, foam insulation piping cut in half lengthwise
- Yard & Meter sticks (used for measuring but also for "guide rails" on the shelf board)
- Vegetable oil, water, sand paper, aluminum foil, bubble wrap
- Stop Watches
- Books or chairs to support one end of the ramp

Process:

The teacher will give the students the inquiry question typed out on a piece of paper (prevents the students from forgetting the original question or from asking for clarification repeatedly).

How can you make your object roll at the greatest average speed?

The teacher will instruct the students that they can use any of the materials laid out on the table to set up their activity, but they must first think through their activity and write out the procedure that they will follow for their initial investigation. The students will bring the teacher their written out procedures along with their materials request. The teacher should look over the procedure for reasonableness and remind the students to try this original investigation for several trials before changing anything. The teacher should not be discussing or giving feedback on selected (or not selected) variables at this time, but should allow initial inquiry and then with questioning, guide the students to discover if they have appropriate controls and variables. Their constraints are:

- The ball must be rolling during their trials
- They must have an initial plan (teacher reviewed)
- They must conduct several trials using the same process
- They must keep track of any additional ideas that they implement

During the activities the teacher will circulate and should be asking students guiding questions, helping them to observe and refine their inquiries. The teacher should ask questions like:

- What pieces of this investigation are remaining the same with each trial?
- What is/was your baseline or control?
- What are you changing to try to get the ball to roll at a greater speed?

- Is there something else you could change (here) or (with this)?

Student Discussion and Evaluation:

Students should be taking notes and recording measurements and times in their science notebook. The activity should be stopped with enough time left for the students to analyze their data, which should include setting it up in an organized manner (table, chart, columns) and doing their calculations for the average speed for each trial. If they deviated from their original plan, then they should have a separate section of data and notes for the results that they observed. Students should be expected to present their data by way of a bar graph as well. Students will be given a 3-2-1 prompt for reflection and then the class will share and have discussion.

3-2-1 Reflection Prompt (students should include this in their notebook write-up)

- What 3 things would you leave the same if you did this again?
- What 2 things would you refine for the next investigation of this question?
- What was the 1 most successful thing that you did?

Activity 3 – Structured Inquiry "A"

This third activity is organized at a "structured inquiry" level[15] meaning that the students will attempt to answer the teacher-given question, WITH a specific prescribed procedure, written and given to them by the teacher. This is the first of two structured inquiry procedures, the first that investigates the results of changing the height of a ramp, the second that investigates the surface of the ramp.

Materials (to be laid out around the room):

- Balls of various sizes, densities and composition (marbles, ping pong balls, golf balls, Styrofoam balls, wooden balls)
- Lengths of shelving board for the ramps
- Books to alter the height of the ramps
- Yard & Meter sticks (used for measuring but also for "guide rails" on the shelf board)
- Stop Watches

Question:

The teacher will give the students the inquiry question:

- *How does altering the ramp height change the average speed of your ball as it rolls?*

Procedure (given to the students)

- Gather your materials – ball, shelf board, stopwatch, books to adjust height, yard or meter stick
- Define your "baseline". Create a ramp by putting the end of one board on the edge of one of your books. Hold your ball on the end of the board (book end) and gently release it to roll without pushing on it with your hand

- Begin timing the ball as you release it; stop timing when it reaches the end of the board. Record this time.
- Repeat this several times and record the time for each trial.
- Increase the height of the end of your ramp and repeat the steps for timing the descent of your ball.
- Continue increasing the height of the ramp until you have at least 3 heights besides your first height (baseline)

Student Discussion and Evaluation:

Students should be taking notes and recording measurements and times in their science notebook. The activity should be stopped with enough time left for the students to analyze their data, which should include setting it up in an organized manner (table, chart, columns) and doing their calculations for the average speed for each trial. Students should be expected to present their data by way of a bar graph as well. They will be given the same 3-2-1 prompt for reflection as given in Activity 2, and then the class will share and have discussion.

Activity 4– Structured Inquiry "B"

This fourth activity is organized at a "structured inquiry" level[16] meaning that the students will attempt to answer the teacher-given question, WITH a specific prescribed procedure, written and given to them by the teacher. This is the second of two structured inquiry procedures, the first ("A") that investigated the results of changing the height of a ramp, and this one that investigates the surface of the ramp.

Materials (to be laid out around the room):

- Balls of various sizes, densities and composition (marbles, ping pong balls, golf balls, Styrofoam balls, wooden balls)
- Lengths of shelving board for the ramps
- Books to set up the ramp at the predetermined height
- Yard & Meter sticks (used for measuring but also for "guide rails" on the shelf board)
- Vegetable oil, water, sand paper, aluminum foil, bubble wrap, masking tape
- Stop Watches

Question:

The teacher will give the students the inquiry question:

- *How does altering the surface of the ramp change the average speed of your ball as it rolls?*

Procedure (given to the students)

- Gather your materials – ball, shelf board, stopwatch, books to set the height of your ramp, yard or meter stick
- Define your "baseline". Set up your ramp by putting the end of one board on the edge of you stack of books. (Use the number of books that was the mid-point height of your

ramps from activity "A") Hold your ball on the end of the board (book end) and gently release it to roll without pushing on it with your hand

- Begin timing the ball as you release it; stop timing when it reaches the end of the board. Record this time.
- Repeat this several times and record the time for each trial.
- Change the surface of your ramp in the following order:
    - Wrap your board in bubble wrap (secure on back of board with tape). Roll your ball at least three times, timing its descent as before and recording the times.
    - Wrap your board in sand paper (secure on back of board with tape). Roll your ball at least three times, timing its descent as before and recording the times.
    - Remove all coverings from your board and wet it with water. Roll your ball at least three times, timing its descent as before and recording the times.
    - Dry off your board as well as possible and then coat the board with a THIN coat of vegetable oil. Roll your ball at least three times, timing its descent as before and recording the times.

Student Discussion and Evaluation:

Students should be taking notes and recording measurements and times in their science notebook. The activity should be stopped with enough time left for the students to analyze their data, which should include setting it up in an organized manner (table, chart, columns) and doing their calculations for the average speed for each trial. Students will be given a 3-2-1 prompt for reflection and then the class will share and have discussion.

3-2-1 Reflection Prompt (students should include this in their notebook write-up)

- What are 3 things that you did differently in this investigation, than you did in the ramp-height investigation?
- What 2 things surprised you during this investigation?
- What 1 thing would you change if you repeated this investigation?

Activity 5 – Open Inquiry

Open inquiry is defined as an investigation that has very little input into it from the teacher. The question under investigation is the student's own question, as is the procedure that they use to investigate their question. The determination of controls and variable is left up to the designer of the activity (the student) and therefore, although not dictated by the teacher, should definitely be overseen in its design by the teacher.

In this unit, the open inquiry can take many forms, but this is the one that I use in my classroom:

> *Come up with an activity to explore further anything you feel would be related to the concept of motion, including the topics of speed, velocity, acceleration, or as we have studied, Newton's first and second laws of motion.*

The student should be required to come up with a specific question to investigate, a procedure for their investigation as well as a materials list. This proposal should be approved by the teacher before the student begins their activities.

The students must be required to keep detailed records of what they do, and the results that they receive. They should be expected to analyze the results, drawing conclusions relating to cause and effect. They will include this in their demonstration of content Knowledge (Activity 6).

Activity 6 – Demonstration of Content Knowledge

At the end of the period of time for these activities, the students should be required to present their understanding of the content. In my class they create an “Infographic” covering the concepts of motion and speed. They will also be given the option to research ahead of time and include the concepts of acceleration and velocity.

Their research sources should include, but not be limited to:

- Their school Science textbook: *Macmillan McGraw-Hill Science*. p. F1-F41.
- Discoveryeducation.com online “Science techbook” (all students in our district have open access to this), Force and Motion Unit (see reference under “Student Resources”).

Appendix 1: Implementing Teaching Standards

Specific standards for this unit include:
Science:
5th grade -- North Carolina Essential Standards (NCES)

- 5.P.1 Understand force, motion and the relationship between them.
    - 5.P.1.1 Explain how factors such as gravity, friction, and change in mass affect the motion of objects.
    - 5.P.1.2 Infer the motion of objects in terms of how far they travel in a certain amount of time and the direction in which they travel.
    - 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.

3rd grade -- North Carolina Essential Standards (NCES)

- NCES.3.P.1 Understand motion and factors that affect motion.
    - NCES.3.P.1.1 Infer changes in speed or direction resulting from forces acting on an object.
    - NCES.3.P.1.2 Compare the relative speeds (faster or slower) of objects that travel the same distance in different amounts of time.
    - NCES.3.P.1.3 Explain the effects of earth's gravity on the motion of any object on or near the earth

Mathematics - Standards for Mathematical Practice:
1 - Make sense of problems and persevere in solving them.
5 - Use appropriate tools strategically.

CCSS.MATH.CONTENT.5.MD.A.1 --Convert like measurement units within a given measurement system.
CCSS.MATH.CONTENT.5.MD.B.2 --Represent and interpret data.

Literacy --
CCSS.ELA-LITERACY.W.4.2 -- Write informative/explanatory texts to examine a topic and convey ideas and information clearly.
CCSS.ELA-Literacy.RH.6-8.7 Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts.
CCSS.ELA-Literacy.SL.4.5 Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes

In addition to the above specific standards I will be incorporating the more subjective skills that deal with persevering in finding a solution and requiring the slow- down on the part of the student, in order to really think through the problem, as opposed to going with the gut reaction to the problem but not really thinking through it.

Appendix 2 – Culminating Assessment

Rubric for Infographic – Activity 6

COMPONENT	EXCEEDS EXPECTATIONS	MEETS EXPECTATIONS	NEEDS MORE WORK
OVERALL IMPRESSION	Infographic "pops" – pulls in reader	Overall quality is mediocre	Rushed, sloppy, not complete in many areas
OBJECTS	Objects are repeated to ease understanding	Some objects repeated, content confusing	Multiple objects used makes for misunderstanding of content
DATA FORMAT	Formats chosen make data presented clear	Some data clear in format chosen. Some of the data unclear	Data not shown in clear format for visualization
FONTS	Good font choice for readable text	Multiple fonts hinder the reading of text	Font choice makes data unreadable
ORGANIZATION	Utilizes ONE: location, alphabetical, category, timeline	Cohesiveness of information with lacking	Random organization of data
COLORS	Color choices enhance the infographic	Too many colors used	Color choices detract from the content
LAYOUT	Layout in inverted pyramid style	Layout design lacks ; content scattered	Lacks either main point, 2nd point, or details
CITATIONS	Full citations included	Some sources listed in part; not complete	No source citations listed

Appendix 3 – Sample Student Work – Data Table and Bar Graph

Table for Ramp Activity

	Ramp Height	Time Average	Distance	Speed
Soccer ball	B.L.=2.5in	5 sec	6 ft	1.2 ft per second
	H.1=3.5 in	4 sec	6 ft	1.5 ft per second
	H.2=6 in	2.6 sec	6 ft	2.3 ft per second
	H.3= 8.5 in	2 sec	6 ft	3 ft per second
Golf ball	H.1=8.5in	2 sec	6 ft	3 ft per second
Ping-Pong ball	H.1=8.5in	2.6 sec	6 ft	2.3 ft per second

Bar Graph

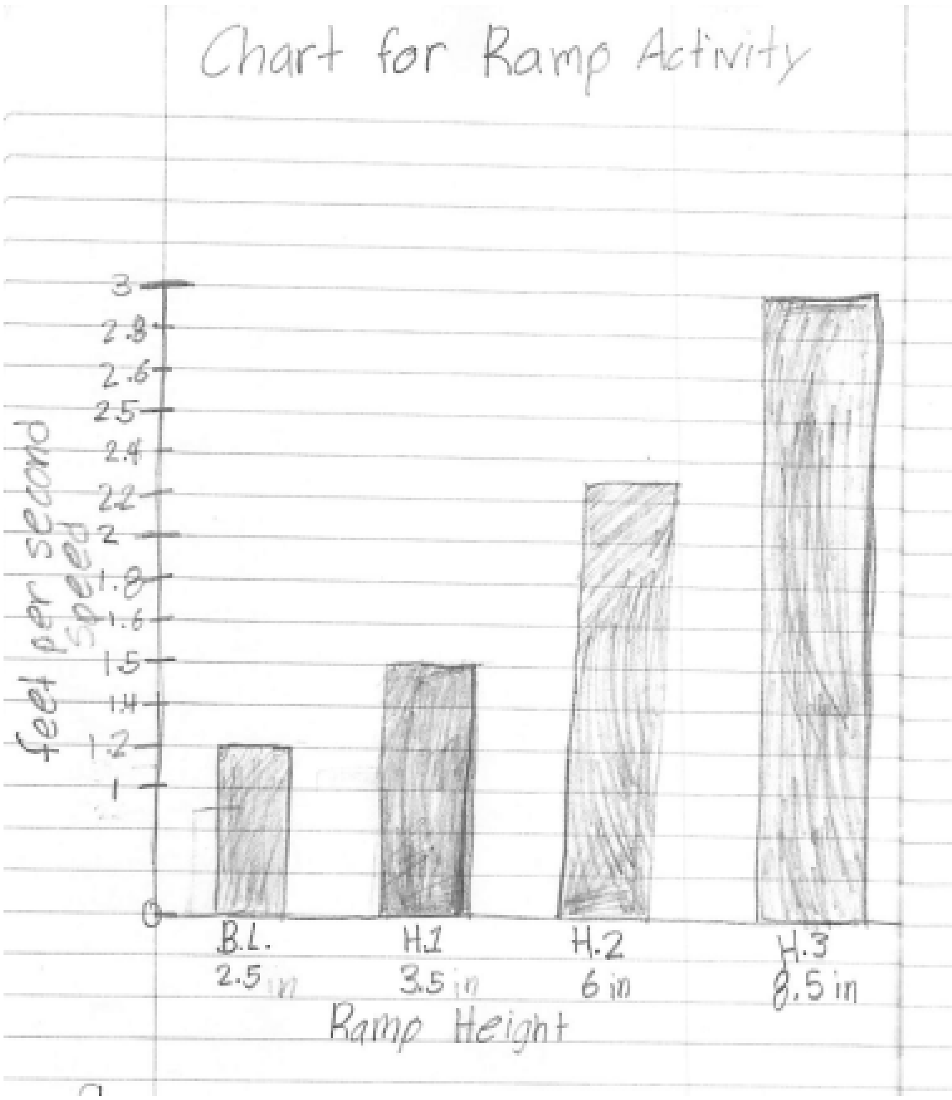
Chart for Ramp Activity
feet per second
speed
3
2.8
2.6
2.5
2.4
2.2
2
1.8
1.6
1.5
1.4
1.2
1
0
B.L.
2.5 in
H.1
3.5 in
H.2
6 in
H.3
8.5 in
Ramp Height

Resources

Materials

Ramp Materials (boards, hot wheel tracks, foam insulation)
Items to coat the ramps with: sandpaper, aluminum foil, bubble wrap, vegetable oil, Rulers, Yard sticks
Graph paper
Content materials (Discovery Education is our go-to source, but the better science textbooks will also work)
Computers, either desk tops or Chrome books

Student Resources

Discovery Education Techbook, available through Discoveryeducation.com. https://app.discoveryeducation.com/techbook2:unit/view/unitGuid/C8F50759-BB57-484D-8840-3C04D4C48216 In Charlotte Mecklenburg Schools, all students have access to this through their student portal. For this unit, the content on Force and Motion is most applicable.

Canva, access at https://www.canva.com/ Canva is super easy design software. Student can create posters, graphics, presentations and infographics.

Daniel, Lucy H., Jay Hackett, Richard Moyer, JoAnne Vasquez. *Macmillan McGraw-Hill Science*. New York, NY: Macmillan/McGraw-Hill, 2006. p.F1-F41.

Google Education Suite (formally GAFE), including Google Docs and Google Drawing. Access at google.com

Kathy Schrock's guide to creating Infographics. This is an excellent reference that walks you through the process of creating an infographic. http://www.schrockguide.net/uploads/3/9/2/2/392267/schrock_google_infographics_0915.pdf.

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Schrock, Kathy . "Google Info-graphics" Retrieved October 12, 2017. http://www.schrockguide.net/uploads/3/9/2/2/392267/schrock_google_infographics_0915.pdf. Excellent "How-To" reference for creating infographics

Volkmann, Mark , and Sandra Abell. "Rethinking Laboratories: Tools for Converting Cookbook Labs into Inquiry ." *The Science Teacher*, 2003, 38-41. doi:TST090303. Contains a great example of taking a traditional lab and making it inquiry.

Notes

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[3] Estes and Dettloff, *Inquiring Minds:Reaching Gifted Students with Challenging Science,* 20
[4] Peters, *Coping 101: Building Persistence and Resilience in Gifted Children,*
[5] "The Growth Mindset - What is Growth Mindset - Mindset Works." https://www.mindsetworks.com/science/. Accessed 16 Sep. 2017.
[6] Khan, Salman https://youtu.be/GWSZ1DKjNzY
[7] Page Keeley, *Doing Science*, Physical Science and Nature of Science Probes, 95
[8] National Research Council, *Inquiry and the national science education standards A Guide for Teaching and Learning*
[9]see [1] above
[10] Volkmann and Abell
[11] see [1] above
[12] Hermann and Miranda, *A Template for Open Inquiry. Using questions to encourage and support inquiry in Earth and Space Science*, 28
[13] Fay and Bretz*, Structuring the Level of Inquiry in Your Classroom,* 40
[14] See [1] above
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[16] See [1] above