Motion Program of Study (grades 3-5) Daily Plan

This document is part of an
Inquiry-based Science Curriculum from
The *Guided Inquiry supporting Multiple Literacies* Project
at the *University of Michigan*

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This project was supported by the following funders:

National Science Foundation
Opinions expressed are those of the authors
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Reach Institute
Opinions expressed are those of the authors
and not necessarily those of the Foundation

Considerations for Helping Students Develop Scientific Understanding about Motion

STANDARD: Describe motion and the principles that explain it.
BENCHMARKS:

- an object's motion can be described by tracing and measuring its position over time.
- an object's motion can be described and represented *graphically* according to its position and speed.
- the position and motion of an object can be changed by pushing or pulling.
- when a force is applied to an object, the object either speeds up, slows down, or goes in a different direction.
- the relationship between the strength of a force and its effect on an object
  (*e.g., the greater the force, the greater the change in motion; the more massive an object, the smaller the effect of a given force*).

Everyday Understandings about Motion

- "Depository" model of energy – some objects have energy and are rechargeable, some need energy and expend what they get, some are neutral
- Only things with energy in them are capable of making changes happen.
- Energy is linked with movement, which leads some to use movement as an indicator of whether energy was present or not.
- Some use the words force and energy synonymously, some treat those concepts as distinct but interconnected
- Energy (being present?) is necessary for movement; energy is a type of force.
- In cases of horizontal motion, force is commonly used in a way that scientists would use kinetic energy.
- Potential energy confused with "potential to have energy." *[perhaps because motion indicates energy*]
- There is something, often called force, within a moving object; it keeps the object moving; it stops moving when this runs out.
- If there is motion there is a force acting and it is proportional to it (constant speed, constant force); no motion no force acting.
- The force is in the direction of the motion.
- Force is a property of a single object rather than a feature of the interaction between objects.

Given these everyday understandings, consider having students develop force and energy models for explaining motion
e.g., Force – use gravity, which is a force common to students; have them establish the relationship between force/mass and motion (balls on ramps, forces measured with spring scales - 1kg ball vs. 2 kg ball, motion is the same, force/mass ratio is the same)
e.g., Energy – use potential energy – height of a ramp – have students establish the conservation of energy as indicated by height
(If a ball has a particular amount of energy at a particular height, what will happen on an opposing ramp if the ball rolls down one ramp and then up another (placed at varying slopes)? how high will the ball go?)

Instructional Path

STANDARD: Understands motion and the principles that explain it

	Types of Motion	**Describing Motion**	**Forces changes Motion**	**Force/Mass & Δ Motion**	**Newton's Laws**
K-2	Knows that things move in many different ways (*e.g., straight line, zigzag, vibration, circular motion*).	Knows that the position of an object can be described by locating it relative to another object or the background.	**Knows that the position and motion of an object can be changed by pushing or pulling.**		
3-5		**Knows that an object's motion can be described by tracing and measuring its position over time.**	**Knows that when a force is applied to an object, the object either speeds up, slows down, or goes in a different direction**	**Knows the relationship between the strength of a force and its effect on an object (*e.g., the greater the force, the greater the change in motion; the more massive the object, the smaller the effect of a given force*).**	
6-8		**Knows that an object's motion can be described and represented graphically according to its position**, direction of motion, **and speed**.	Understands effects of balanced and unbalanced forces on an object's motion (*e.g., if more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude; unbalanced forces such as friction will cause changes in the speed or direction on an object's motion*).		Knows that a moving object that is not subjected to an additional force will continue to move at a constant speed and in a straight line.

GIsML MOTION Program of Study

Instructional Path

Phase	Focus	Teacher Activity	Student Activity
Engage [Cycle 1]	Reason for studying motion.	Pose question of what will happen when balls of different mass are set in motion – will they travel in the same way or differently? • If they are rolled across the table, do you think they will get to the end point at the same time or a different time? • If they are rolled down a ramp, do you think they will get to the end point at the same time or a different time? If student(s) think the outcome would be different, ask why. Show phenomenon: • balls on flat surface [lighter ball gets to end first] • balls down a ramp [balls get to the end at the same time] (or the heavier ball gets to the end first) How do these results compare? [Difference in effect of mass on ramp in contrast to effect of mass in motion across the table.] How can we make sense of these results? We will be studying the motion of carts to determine how we can explain these differences.	Make prediction and describe reasoning. Make prediction and describe reasoning. Describe observations (& record?). Describe observations. Describe pattern for each.
	How will we study motion to find out? Try out methods for measuring motion. [Canned Speed - SAE *World in*	If we are to study motion, • what can we observe? measure? how? We are going to measure a person in motion in different ways (walk, hop, skip). We want to be able to accurately and precisely compare these motions. There are different ways that we can measure, so let's see what happens when	State possible variables.

[1] The fewer times a variable is measured the less the amount of error, and the fewer number of variables measured the less the amount of error. In this case the method with the least error is to measure a set distance, and determine the time it takes a moving object to travel that distance.

Phase	Focus	Teacher Activity	Student Activity
	Motion]	we try different ways. What do we need to measure? 1st - count *set* time, measure distance • After first trial of each motion (walk, hop, skip), ask Ss which was fastest and how to tell considering what was measured. • After speed discussion, ask Ss about their confidence in the accuracy of the result. If Ss are not confident, ask them what could be done to do to be more confident in the results. If needed, suggest the idea of other trials. Continue conducting trials until Ss indicate they are confident in the results. • After multiple trials, ask Ss how to use data to calculate speed. Introduce calculation of speed. Ask Ss what to do with the data across trials. If needed, suggest the idea of averaging. 2nd - count time over a *measured* distance • After first trial, ask Ss about their confidence in the result and how to proceed. Have Ss determine how many trials to conduct. • Ask Ss how to deal with data to calculate speed. Check for uptake of idea of averaging, and if not mentioned ask students how data from multiple trials were handled in the previous context. • repeat for each type of motion (walk, hop, skip) 3rd - for motion over a *set* time w/stopwatch, measure distance traveled • prompt students for how to collect data (multiple trials)	State variables. Each round different students (Ss) take roles of: timekeeper-counting, timekeeper-stopwatch, person measuring distance, person in motion, person recording data State views about fastest motion, how to determine speed quantitatively from the data.[2] Indicate opinions about the number of trials needed to have confidence in the accuracy of the data. State ideas about how to determine speed. State ideas about how to combine information from multiple trials. State ideas about how many trials to conduct. Provide evaluations, suggest best methods to use.

[2] It is important for students to understand that the number for speed represents information about distance AND time, but that it can refer to the motion at an instant, regardless of how far something has traveled or for how long a time. At the same time, students should understand that if the speed is known, one could tell how much time it would take an object to travel a particular distance and how far the object would travel in a particular amount of time.

Phase	Focus	Teacher Activity	Student Activity
		and how to analyze data (averaging to have data for calculation of speed) • repeat for each type of motion (walk, hop, skip) 4th - measure time (stopwatch) of travel over a *measured* distance. • conduct in the same way as the 3rd context Ask Ss to compare results for the four contexts and evaluate them in terms of the accuracy of the resulting data Have Ss indicate which method(s) they think limit the amount of error in the data.[1]	
Prepare to Investigate	Set context for inquiry.	Show Ss materials they will have to work with (car, rubberband chain stretched between chair legs). Ask for ideas about how to: • consistently get the car moving in the same way • systematically change the force to get the car moving in order to see effects of force on motion Ask for descriptions about how to measure the motion w/precision; calculate the speed.[3]	 State ideas and reasoning. State ideas and reasoning. State ideas and reasoning.
	Set the timeframe for investigating.	State time for investigation, indicating that results will be shared with the class, but that more formal discussion of what that will entail will occur after the investigation. Indicate when teacher (T) will give alerts to help Ss monitor progress toward completing investigation (set up, collect data, prepare data table).	Ask questions if unclear about responsibilities.
Investigate - *influence*	Collecting Data	Monitor for thoughtfulness and decision-making about: • consistency in use of materials and procedures	Set up procedures to systematically collect and precisely measure data (*time, force,*

[3] Look for appropriation of the method deemed to result in the least amount of error (i.e., having a set measured distance and determining the time of travel over that distance), but do not privilege its use by all students at this time. Also look for appropriate of multiple trials, the total number conducted being determined by Ss as a function of their confidence in the accuracy of the results, which can differ for each condition.

Phase	Focus	Teacher Activity	Student Activity
of force on motion		(e.g., location of blue rods on car) • number of trials to feel confident about data Monitor for thoughtfulness about procedures to ensure: • reasonable control of force and meaningful differences in results from different forces • measurement of distance in precise ways • measurement of time in precise ways	*distance*). Collect data with sufficient accuracy and precision, and in sufficient quantities.
Prepare to Report	Analyzing Data Preparing Poster Report	Monitor for decision-making about how and what data to graph (if not ready for graphing, that can wait until the next cycle). Monitor for awareness of what should be on poster (claims & evidence); assist with increasing size of graphs as needed.	Prepare graphs of relevant data. Prepare Poster Report of Claim(s) about motion with accompanying evidence.
Report	Procedures and Findings in Investigation of Motion	Monitor for thoughtfulness about influence on claims of choices in methods and materials. Ask for indication of agreement with each group's claim(s) to determine whether or not there is consensus about each claims.[4] Ask Ss what might be next steps where there is uncertainty or disagreement. • Monitor for everyday views of force (conflation with motion or energy); can introduce idea of momentum, energy, etc. if needed to support accurate reasoning about motion.	Participate in giving group report. Ask other groups questions as needed to ensure accuracy and understanding of others' claims and evidence. State agreement with claim(s). Discuss meaning of claims and next steps to take to advance thinking about explaining motion.
Engage [Cycle 2]	Determine direction of next Investigation	Ask Ss to state their ideas about direction for next cycle of investigation – questions and contexts. • If degree of uncertainty/disagreement regarding class	Determine statements of next questions to answer and the contexts to use to investigate the questions.

[4] Where there is uncertainty or disagreement about claims is particularly important because these are natural contexts for more investigation; students should be helped to recognize that further investigation is the way scientists would respond to such situations.

Phase	Focus	Teacher Activity	Student Activity
		claim discussion is high, press Ss to continue to investigate the same question as before (the amt. of force and motion) to come to greater agreement.	
Prepare to Investigate	Nature of optimum conditions	Assuming the same context (investigation of force-motion relationships), ask Ss to describe optimum conditions. • reliable method for consistent amount of force • great enough difference in amount of force that there are meaningful differences in the result[5]	Ss state ideas about methods.
Investigate - *influence of force on motion*	Collecting Data[6]	Monitor for thoughtfulness and decision-making about: • consistency in use of materials and procedures (e.g., location of blue rods on car) • number of trials to feel sure about data Monitor for thoughtfulness about procedures to ensure: • reasonable control of force and meaningful differences in results from different forces • measurement of distance in precise ways • measurement of time in precise ways - expectation of this variable to be measured each time (trial or test)	Set up procedures to systematically collect and precisely measure data (*time, force, distance*). Collect data with sufficient accuracy and precision, and in sufficient quantities.
Prepare to Report	Analyzing Data Preparing Poster Report	Monitor for decision-making about how and what data to graph - be sure to expect graphed data this time if graphs were not constructed in the first cycle. • plot time on the x-axis and force on the y-axis; • speed can be plotted for those who wish to calculate it, but then the graph should be force on the x-axis and speed on the y-axis Monitor for awareness of what should be on poster (claims & evidence); assist with increasing size of graphs as needed.	Prepare graphs of relevant data. Prepare Poster Report of Claim(s) about motion with accompanying evidence.

[5] Scientists typically explore extreme cases (variables at very high and very low values and a few point inbetween) to maximize their opportunities to see differences in results if there will be differences.

[6] For students who previously were unable to draw conclusions from their data, this opportunity to try again is key to their learning.

Phase	Focus	Teacher Activity	Student Activity
Report	Procedures and Findings in Investigation of Motion	Monitor for thoughtfulness about influence on claims of choices in methods and materials. Ask for indication of agreement with each group's claim(s) to determine whether or not there is consensus about each claims.[7] Ask Ss what might be next steps where there is uncertainty or disagreement. • Monitor for everyday views of force (conflation with motion or energy); can introduce idea of momentum, energy, etc. if needed to support accurate reasoning about motion. • Monitor for interpretation of graphs and the nature of the relationship indicated by the shape of the line on the graph.	Participate in giving group report. Ask other groups questions as needed to ensure accuracy and understanding of others' claims and evidence. State agreement with claim(s). Discuss meaning of claims and next steps to take to advance thinking about explaining motion.
Engage [Cycle 3]	Determine direction of next Investigation	Ask Ss to state their ideas about direction for next cycle of investigation – what other variable do Ss think is likely to influence the motion of the cart? • If needed, scaffold Ss in describing the various ways (variables) they can change the cart.	Determine statements of next questions to answer and the contexts to use to investigate the questions.
Prepare to Investigate	Nature of optimum conditions	Assuming the same context (carts set into motion with rubberbands), tell Ss that the mass of the cart can be changed with adding washers. • ask about how might determine amounts of mass to test[8] • raise issue (if not raised by Ss) about needing enough difference in amount of mass that there are meaningful	Ss state ideas about methods, ways to check for stability of cart with washers.

[7] Where there is uncertainty or disagreement about claims is particularly important because these are natural contexts for more investigation; students should be helped to recognize that further investigation is the way scientists would respond to such situations.

[8] It can be fine in this case to collect data by increasing by only one washer at a time; however, it is good practice to help Ss consider other intervals for exploring the influence of the amount of mass (e.g., by 2s, 3s)

Phase	Focus	Teacher Activity	Student Activity
		differences in the result, if there are going to be differences[9] Be sure to have Ss discuss possible problems of the stability of the cart with the washers.	
Investigate - *influence of mass on motion*	Collecting Data	Monitor for thoughtfulness and decision-making about: • consistency in use of materials and procedures (e.g., location of washers on car) • number of trials to feel confident about data - question always asked anew in new contexts Monitor for thoughtfulness about procedures to ensure: • meaningful differences in results from different masses • measurement of distance in precise ways • measurement of time in precise ways	Set up procedures to systematically collect and precisely measure data (*time, mass, distance*). Collect data with sufficient accuracy and precision, and in sufficient quantities.
Prepare to Report	Analyzing Data Preparing Poster Report	Monitor for decision-making about how and what data to graph - mass should be plotted on the y-axis. Monitor for awareness of what should be on poster (claims & evidence); assist with increasing size of graphs as needed.	Prepare graphs of relevant data. Prepare Poster Report of Claim(s) about motion with accompanying evidence.
Report	Procedures and Findings in Investigation of Motion	Monitor for thoughtfulness about influence on claims of choices in methods and materials. Ask for indication of agreement with each group's claim(s) to determine whether or not there is consensus about each claims.[10] Ask Ss what might be next steps where there is uncertainty or disagreement. • Monitor for everyday views of relationship of mass to speed; i.e., association of mass with speed rather than momentum (which takes into account speed and mass).	Participate in giving group report. Ask other groups questions as needed to ensure accuracy and understanding of others' claims and evidence. State agreement with claim(s). Discuss meaning of claims and next steps to take to advance thinking about explaining motion.
Engage	Putting relationship	Ask Ss how they would put together relationships of mass	Ss state their ideas about the inverse

[9] This context is somewhat limited in this case because the cart cannot hold that many washers and it is light enough that a few washers can make a significant difference.

[10] Where there is uncertainty or disagreement about claims is particularly important because these are natural contexts for more investigation; students should be helped to recognize that further investigation is the way scientists would respond to such situations.

Phase	Focus	Teacher Activity	Student Activity
[Cycle 4]	with mass and force together	and force on the motion of a cart. Tell Ss that the class has the opportunity to study the notes of a scientist doing work in a similar fashion, only the work was exploring force and mass at the same time.	relationship between the influence of force on motion and the influence of mass on motion.
Investigate & Report	*2nd-hand investigation*: influence of force AND mass on motion on a level surface	Interactively read scientist's notebook text about the relationship between force and mass and the motion of an object. • support Ss in noting types of information in text - questions, nature of investigation, data, claims • support Ss in interpreting text - at the level of comprehension of text AND at the level of providing rationale for actions of the scientist [text ends with the prob. that mass does not make a difference in movement down a short ramp - this sets up the opportunity to discuss and explore initial force versus constant force]	Ss read text interactively with T Ss ask questions as need if not clear about what is represented in the text or its significance
Engage [Cycle 5]	Initial versus constant force	Ask Ss how they would think about the difference between the motion of a cart when given only an initial force vs. a constant force. Pose question of what will happen when balls are set in motion by different forces, impetus and constant – will they travel in the same way or differently? If student(s) think the outcome would be different, ask why.	Ss state their ideas about the difference between motion related to an initial force and motion related to a constant force.
Prepare to Investigate	Nature of optimum conditions	In the new context (carts set into motion with a wound-up rubberband linked to a propeller), shows Ss the motion of the cart. • ask about how might determine how to control and manipulate the force (windings of the rubberband), and about the issue of the degredation of the rubberband over time due to the stretching • raise issue (if not raised by Ss) about needing enough	Ss state ideas about methods, ways to monitor for degredation of rubber band over time.

Phase	Focus	Teacher Activity	Student Activity
		difference in amount of force that there are meaningful differences in the result, if there are going to be differences[11]	
Investigate - *influence of constant force on motion*	Collecting Data	Monitor for thoughtfulness and decision-making about: • consistency in use of materials and procedures (e.g., number of windings of rubberband) • number of trials to feel confident about data - question always asked anew in new contexts Monitor for thoughtfulness about procedures to ensure: • meaningful differences in results from different amount of force due to the rubberband • measurement of distance in precise ways • measurement of time in precise ways	Set up procedures to systematically collect and precisely measure data (*time, force, distance*). Collect data with sufficient accuracy and precision, and in sufficient quantities.
Prepare to Report	Analyzing Data Preparing Poster Report	Monitor for decision-making about how and what data to graph - force should be plotted on the y-axis. Monitor for awareness of what should be on poster (claims & evidence); assist with increasing size of graphs as needed.	Prepare graphs of relevant data. Prepare Poster Report of Claim(s) about motion with accompanying evidence.
Report	Procedures and Findings in Investigation of Motion	Monitor for thoughtfulness about influence on claims of choices in methods and materials. Ask for indication of agreement with each group's claim(s) to determine whether or not there is consensus about each claims.[12] Ask Ss what might be next steps where there is uncertainty or disagreement. Press for thinking about difference between initial for and constant force[13].	Participate in giving group report. Ask other groups questions as needed to ensure accuracy and understanding of others' claims and evidence. State agreement with claim(s). Discuss meaning of claims and next steps to take to advance thinking about explaining motion.
Engage	Force required to	Ask Ss how they think about the force required to get	Ss state ideas about why different amount of

[11] It may take as many as 50 windings to have enough force to support the cart in going a measureable distance (in a reliable way).

[12] Where there is uncertainty or disagreement about claims is particularly important because these are natural contexts for more investigation; students should be helped to recognize that further investigation is the way scientists would respond to such situations.

[13] Keeps the speed up for a longer period of time, but general relationships should be the same.

Phase	Focus	Teacher Activity	Student Activity
[Cycle 6]	overcome friction	something to move. Begin to discuss the importance of the contact surfaces.	forces are required to move the same object on different surfaces.
Investigate - *influence of mass on motion in situation of constant force*	Collecting Data and measuring friction on inclined plane and flat surface	Monitor for thoughtfulness and decision-making about: • consistency in use of materials and procedures (e.g., use of spring scale, angle of inclined plane) • number of trials to feel confident about data - question always asked anew in new contexts Monitor for thoughtfulness about procedures to ensure: • meaningful differences in results from different amount of frictional force • measurement of incline in precise ways • measurement of frictional force in precise ways	Set up procedures to systematically collect and precisely measure data (*time, mass, distance*). Collect data with sufficient accuracy and precision, and in sufficient quantities.
Report	Procedures and Findings in Investigation of Motion	Monitor for thoughtfulness about influence on claims of choices in methods and materials. Ask for indication of agreement with each group's claim(s) to determine whether or not there is consensus about each claims. Ask Ss what might be next steps where there is uncertainty or disagreement. Press for thinking about differences among the forces required to start an object in motion	Participate in giving group report. Ask other groups questions as needed to ensure accuracy and understanding of others' claims and evidence. State agreement with claim(s). Discuss meaning of claims and next steps to take to advance thinking about explaining motion.
Engage [Cycle 7]	Questioning the force of gravity and the influence of mass on motion on an inclined plane.	Ask Ss how they would put together relationships of gravity and mass on the motion of a cart on an inclined plane. Tell Ss that the class has the opportunity to study the notes of a scientist doing work in a similar fashion.	Ss state their ideas about the relationship between the influence of gravity on motion and the influence of mass on **motion**.
Investigate & Report	*2nd-hand investigation*: influence of gravity on motion	Interactively read scientist's notebook about the relationship between gravitational force and mass and the motion of an object. • support Ss in noting types of information in text - questions, nature of investigation, data, claims • support Ss in interpreting text - at the level of comprehension of text AND at the level of providing	Ss read text interactively with T Ss ask questions as need if not clear about what is represented in the text or its significance

Phase	Focus	Teacher Activity	Student Activity
		rationale for actions of the scientist [text solves the problem that mass does not make a difference in movement down a short ramp because the scientist measures that the amount of force on more massive objects is greater -- thus, the apparent equality of force at the same height is not accurate]	

