Science of Driving

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SAFEty Research using SIMulation

UNIVERSITY TRANSPORTATION CENTER

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A Report on Education Sponsored by

Safer Sim University Transportation Center

August 2016

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Abstract

The Science of Driving project focused on developing a collaborative relationship to develop curriculum units for middle school and high school students to engage them in exciting real-world scenarios. This effort involved faculty, staff, and students from the Colleges of Education, Business, and Engineering who worked to link Next Generation Science and Engineering Standards to the reality of driving. This resulted in the development of three curriculum units focused on graphical interpretation, friction, and distracted driving. These curriculum units were provided to over 56 in-service teachers with a potential to impact 7,700 students. Future development will include a new website to expand the reach of the curriculum modules across the country.

1 Background

The federal government has identified a critical need for additional STEM workers as the nation moves forward. In April 2012, a report issued by the U.S. Congress Joint Economic Committee chairman's staff identified that improving access to STEM education is required to strengthen the U.S. workforce to compete in the world economy. In many cases, it remains a challenge to get school-aged children excited about STEM classes, which can often be more challenging. There is a critical need for outreach to teachers and students to make this content more relevant and approachable.

As children grow and develop, there is an increasing desire for independence. Independent mobility is a key factor that allows adolescents access to their friends, educational opportunities, recreational activities, and employment. For many, obtaining a license is a "rite of passage" that leads to this independence. School-aged children aged 13-16 are often very interested in and motivated by driving as they approach getting their license. Building on this interest creates an opportunity to introduce STEM concepts to these teens through an interactive driving simulation environment.

2 Approach

The research project involved the development, testing, and implementation of a driving-based curriculum for STEM education. This effort was geared toward two endpoints, professional development (PD) and classroom-based lab (CL). Both focused on enhancing STEM education through a "Science of Driving" paradigm. This included the development of lesson plans that can be utilized in these two approaches and the development of necessary driving simulator scenarios and data reduction scripts to make the data usable for students and teachers. The aim of the PD was an in-depth exposure to the curriculum modules including data and how it can be used to understand the physics of driving, what drivers are doing, and how systems can be evaluated. Additionally, the PD provided feedback on gaps in the curriculum. The aim of the classroom course is to provide context and allow students to collect data that they can use to address an immediate question and in future lessons.

2.1 SaferSim Curriculum Module Development

A team of science education graduate students from the College of Education and their professor, Dr. Leslie Flynn, engaged with the National Advanced Driving Simulator (NADS) staff to tour the NADS facility and learn the SaferSim program and current capabilities of the miniSim. Across the course of the semester, students developed two independent curricular, instructional, and assessment modules that complement the miniSim experience. Students communicated frequently with NADS staff to make sure they were meeting expectations and the content was accurate. The modules were aligned to national science and mathematics standards including conceptual understandings (force, motion, friction, velocity, etc.) and practices of science (making observations, asking questions, analyzing and interpreting data, etc.). Additionally, PD activities were developed for use with teachers. Following the initial PD, a team of science education graduate students from the College of Education and their professor, Dr. Flynn, engaged with NADS staff to adapt the developed curriculum material based on feedback from the teacher PD.

2.2 SaferSim Teacher Professional Development

The curriculum modules were used during the fall 2015 PD institute and distributed to 56 in-service and 21 pre-service teachers in 2016 to expand the learning opportunities of their students who could work with miniSim. In the fall of 2015, 9 in-service and 2 pre-service STEM teachers engaged in a full day of PD and explored the NADS facility and engaged with SaferSim. The teachers engaged in the curriculum modules and made curricular, instructional, and assessment suggestions for revision. Facilitating the PD were three science education graduate students who developed the modules, Dr. Flynn, and NADS staff. Dr. Flynn also facilitated a school-year follow-up to see how curriculum materials had been incorporated into classroom practice and how students responded to the lessons.

2.3 SaferSim Teacher Classroom Labs

Utilizing the curriculum developed in the other tasks, classroom labs were coordinated to provide hands-on experiences for students and to provide context to the data. Local schools and teachers were recruited to participate. This was facilitated through contact with teachers in the PD program and through the local Area Education Associations and the Kirkwood Regional

Center at the University of Iowa, next door to NADS. The number of classes conducted at each school was dependent on the size and participation from the interested schools. The classroom lab was offered both as a full implantation of the curriculum and as an augmentation to existing curriculum in use in the district. In the case of augmentation, the simulation and related activities were used to either introduce or reinforce a concept or a practice of science. For the classroom sessions, the course was conducted and feedback was obtained from the teacher. A portable miniSim was set up at the school to allow for the collection and processing of data that was used by the students for exploration of STEM concepts and practices as part of the assigned lesson and subsequent lessons conducted by the teacher. Simulator data was sent back to teachers approximately one week after the simulator visit.

3 Curriculum

Curriculum was developed in three units: graphing interpretation, friction, and texting. Each is a fully developed curriculum component that includes all instruction and assessment tools for implementation, and all units are mapped to National Science and Engineering Standards. This section details the development process in more detail, summarizes each of the curriculum units, and outlines the PD.

3.1 Development Process

The process to develop the curriculum was an iterative process between NADS and the College of Education at the University of Iowa. It provided the side benefit of additional STEM exposure and educational opportunities to teachers-in-training. The process used the following steps, with the most effort associated with the iterative development, testing, and refinement of the curriculum and scenarios.

Step 1: Familiarize pre-service teachers with simulator capabilities

Step 2: Identify potential driving tasks that could tie into National Standards

Step 3: Investigate identified topics

Step 4: Develop outline of curriculum

Step 5: Specify simulator scenario and data requirements

Step 6: Develop, test, and refine curriculum and scenario

Step 7: Develop PD material

Step 8: External test of curriculum and driving simulations

Step 9: Revise and finalize curriculum and professional material

Figure 3.1 - Student texting and driving simulation.

3.2 Curriculum Summary

The curriculum for a physics unit on motion teaches students about graphing and factors that influence motion, such as friction and distracted driving. It contains lesson plans, classroom activities, and assessments designed for the middle school level. This curriculum uses modern-day simulations provided by NADS and relates classroom concepts and the practices of science to real-world experiences. These curricular attributes engage students and make physics content relevant. The curriculum assists in meeting many standards for math, science, reading, and comprehension from the Iowa Core and Next Generation Science Standards (NGSS). This curriculum is designed to be used with a miniSim simulator provided by NADS, but it is also flexible enough that teachers can use individual lessons without the simulator to fit their needs.

The three pieces of curriculum developed are related to graph interpretation, friction, and distracted driving. These concepts are easily demonstrated in a simulator. The graph interpretation is a foundational skill that is required in all STEM fields, and it can be difficult for students to comprehend the complexity and amount of information available in a single graph or sets in several interrelated graphs. The friction concept can be difficult for students to experience and represent graphically with data. The simulator provides a demonstration that can be easily understood from personal experience and provides real-time data for analysis and interpretation. The distracted driving lesson allows students to extend their learning from the graphing interpretation lesson and apply new graphing skills and interpretation to a common scenario they may experience in their daily life: texting and driving.

3.3 Graphing Interpretation Competition

3.3.1 Goals

To give students the skills to analyze and construct graphs (position vs. time, velocity vs. time, acceleration vs. time, and direction vs. time).

3.3.2 Justification

Students are often introduced to graphs, but according to the teachers consulted, students rarely have the ability to fully analyze and describe them. Graph interpretation is needed in many professions and in day-to-day life, and is seen on many standardized tests. By introducing students to graphing early, they will be given the opportunity to improve graphing skills throughout middle school and high school.

3.3.3 Lesson One: On the Move

The introduction to graphing motion starts with probes to discuss the misconceptions. An activity follows to engage students in kinesthetic learning and produces data that is graphed. Velocity and acceleration are calculated based on the data acquired.

3.3.4 Lesson Two: Graphing Complex Motion

Students use their homework to evaluate position (distance), speed, acceleration, and direction for complex motion. Students analyze the trip they wrote for their homework from the perspectives of distance, speed, acceleration, and direction to be used to graph the motion. The teacher asks students to draw a data set consisting of four graphs by the end of class: (1) distance vs. time, (2) speed vs. time, (3) acceleration vs. time, and (4) direction vs. time. Students are then expected to analyze a data set of a new situation and determine the trip events in order for complex motion. Students work in groups of four, and roles for the simulator are assigned.

3.3.5 Lesson Three: Simulation Driving Day

Groups should finalize their driving plan before driving the simulator to replicate the graphs given to them the prior day. Afterwards, NADS-generated graphs are compared to the activity graphs. An assessment follows NADS simulation and graph comparison.

3.4 Friction

3.4.1 Goals

To educate middle school students about friction and how it affects driving: Students will understand that there are forces and factors that influence motion, including mass, velocity, and friction.

3.4.2 Justification

Middle school students have many misconceptions about physics, particularly in friction. These misconceptions are as follows:

- Friction is caused by surface roughness (there are many times when this is indeed true, but there are other times where a surface may not be as rough but still has more friction, e.g., the sticky side of tape is less rough than sandpaper but has more friction)
- An object doesn't stop because of the presence of a force; it stops because of the absence of a force
- Objects at rest have no forces acting on them
- Moving objects come to a stop even when there is no friction
- Friction only occurs between solids
- There are tiny bumps that cause friction (the use of sandpaper)
- Friction always hinders motion; reducing friction is always desired

The science teacher should address these misconceptions, identify where they come from, and provide experiences for students to address their conceptions to prevent them from recurring.

3.4.3 Lesson One: Factors that Affect Motion

This lesson serves as an introduction to the driving simulator activity. Students collect data and draw conclusions about how different variables such as mass, velocity, and friction affect motion. Students are then introduced to the stopping distance calculation that they will use in the driving simulation activity.

3.4.4 Lesson Two: Simulation Driving Day

The purpose of the lesson is to have students collect data on stopping distance using a combination of variables. Students are assigned their variable combination and are to complete their calculations predicting the stopping distance needed with that variable combination. The variables are car type (either the BMW or Expedition) and coefficient of friction (COF) (0.85, 0.4, or 0.2). There are six possible car and COF combinations: BMW+0.85 COF, BMW+0.4 COF, BMW+0.2 COF, Expedition+0.85 COF, Expedition+0.4 COF, and Expedition+0.2 COF. Students drive the simulator for their given variables. The simulation will be set up to match each group's variable combination when they arrive at the simulator. After students run the simulation for their assigned variables, they record their results, discuss their results with class members, and partake in journaling as an assessment.

3.4.5 Lesson Three: Finalizing Friction

Students are given a quiz to assess their understanding of the concepts that were used in the previous lessons. After the quiz, students engage in either an open or guided discussion of the simulation activity and/or discuss the concepts themselves, clearing up any misconceptions that still persist. There may also be opportunity for further journaling.

3.5 Professional Development

Professional development for teachers who will implement the Science of Driving curriculum is an essential element for incorporation into existing school curricular, instruction, and assessment practices. Our approach is to provide multiple experiences for teachers across several years to increase the likelihood of implementation. Research indicates that this approach is effective in translating teacher learning into practice to impact student learning outcomes [1]. In total, the project has provided PD opportunities for 56 in-service and 21 pre-service teachers. With continued PD these teachers have the capacity to impact 7,700 students annually (100 students/teacher).

A key to continued teacher PD and implementation has been the partnership between the NADS team and the College of Education. Collectively we have been able to leverage our resources and expertise to maximize exposure of the curriculum to teachers. Dr. Flynn engaged 21 pre-service teachers in her undergraduate and graduate school courses in science education across two semesters (fall 2015 and spring 2016). In addition, 56 in-service teachers participating in a three-year PD program, STEM Innovator (SI), were provided curriculum for implementation. STEM Innovator is a PD program to infuse innovation and entrepreneurship into K-12 curriculum by working with STEM community partners. The program is a collaboration between the University of Iowa Colleges of Engineering, Education, and Business. The SI program has partnered with the U.S. Patent and Trademark Office, and this provides an opportunity to expand implementation of the Science of Driving curriculum to a national audience in 2017.

4 Development Process

Step 1: Identification of existing PD opportunities to incorporate curriculum

Step 2: Identification of new PD opportunities

Step 3: Needs assessment of in-service teachers

Step 4: Pilot testing of PD curriculum Units 1 (graphing) and 2 (friction) by pre-service teachers and Dr. Flynn

Step 5: Development of December 2015 PD

Step 6: Delivery of December 2015 PD

Step 7: Revision of curriculum Units 1 and 2 based on teacher feedback from December 2015 PD

Step 8: Development of Unit 3 curriculum (distracted driving)

Step 9: Pilot testing of Unit 3 PD activities with pre-service teachers

Step 9: Revision of Unit 3 PD activities by Dr. Flynn, pre-service teachers, and NADS

Step 9: Pilot testing of Unit 3 with in-service middle school teachers and students

Step 10: Introduction of curriculum to 56 middle and high school teachers at STEM Innovator teacher conference (June 2016)

Step 11: Planning of next steps for additional PD

5 Next Steps

Dr. Flynn's pre-service teachers of fall 2016 are engaging with NADS and high school students to develop additional driving scenarios around teen driving. The goal is to incorporate the scenarios into additional curricular unit opportunities for teachers in 2017. Through the STEM Innovator teacher PD program, there is an expansion opportunity to have NADS serve as a national model for curriculum development and PD implementation in the arena of transportation education.

6 Outreach

Implementation of the curriculum and related materials is a critical aspect of evaluating the success of this project. As discussed earlier, two forms of outreach were used to expose students to the developed lessons. The first, and most straightforward, was the classroom labs. This involved providing support for the curriculum exactly as documented in the curriculum by working with the teachers. The second approach was more complex and involved miniSim demos for teachers. In this method, we worked with teachers to determine how the curriculum material could be used to enhance the learning experiences of their students. This generally involved the following approaches: introducing new topics before the teacher covered it with their existing curriculum and/or reinforcing previous lessons through the simulator experience.

A typical miniSim demo involved working with the teacher to prepare for the demo, working on demonstration day, and providing data for the students and teacher. The preparation work began with conversations between a coordinator at NADS and the teacher about content and dates. During this portion, the material for the overall curriculum was shared to help determine what was to be covered during the demo. On the demonstration day, a team was present at the school for the entire day and went through the agreed-upon material relating to graphing and friction with the students. This may have included students from multiple teachers, depending upon class size and number of sections. At the end of the day, data from the student drives was reduced and provided to the teacher for use with the class.

During the outreach portion of the project, key efforts were with the Mt. Pleasant, Bettendorf, and Norwalk school districts. More than 500 students were exposed to the curriculum through these outreach efforts during the spring of 2016.

Figure 6.1 - Classroom of students watching another student driving the simulation on friction.

Figure 6.2 - A male middle school student driving a simulation scenario in front of his class in Norwalk, Iowa.

Figure 6.3 - A female middle school student driving the texting simulation scenario in front of her class in Norwalk, Iowa.

Figure 6.4 - Students receiving instruction before driving the simulator.

Figure 6.5 - Students discussing the classroom portion of the curriculum.

Figure 6.6 - A male student from Bettendorf Middle School driving the texting simulator scenario.

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Figure 6.7 - Students observing another student driving the simulator.

Figure 6.8 - Students in Bettendorf, Iowa, engaged and answering questions prior to a drive on the simulator.

7 Conclusions, Recommendations, and Future Work

This effort has provided the foundation for continued work to provide K-12 STEM curriculum that is tied to national standards for use in the classroom. Overall the teachers and students that we have interacted with provided positive responses to the material in the curriculum and are excited for future developments. Despite only providing the material for one semester, there was tremendous interest, which will allow us to increase our outreach moving forward.

The process of collaboration between the College of Education and NADS creates the opportunity to add additional lessons using the same process. The integration of this development with Dr. Flynn's class also allows for a richer educational opportunity for the teachers in training. The plans include continued collaboration to develop additional lessons on other topics related to driving, with a new lesson being completed or refined each year.

In addition to providing the classroom component, the team is planning to begin the process of developing a web page as a resource for K-12 schools. It would include the ability to download curriculum, request lab or demo visits, and access videos and data that could be used by teachers across the country who do not have access to the simulator for a visit.

References

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Appendix A Curriculum Materials for Graphing and Friction

THE NATIONAL ADVANCED DRIVING SIMULATOR

THE UNIVERSITY OF IOWA | COLLEGE OF EDUCATION

Leaders. Scholars. Innovators.

Graph Interpretation and Motion Investigation for Junior High/Middle Students

Curriculum Overview

This curriculum, for a physics unit on motion, teaches students about graphing and factors that influence motion, such as friction. It contains lesson plans, classroom activities, and assessments designed for the middle school level. This curriculum uses modern-day simulations provided by The National Advanced Driving Simulator (NADS) and relates classroom content to real-world experiences. Both of these attributes will engage students and make physics content relevant. The curriculum assists in meeting many standards for math, science, reading, and comprehension from the Iowa Core and Next Generation Science Standards (NGSS). This curriculum is designed to be used with a portable MiniSim simulator brought into your classroom by NADS, but it is also flexible enough, so teachers can use individual lessons to fit their needs.

This project was funded by a Safer-Sim Department of Transportation grant.

This project was created by The University of Iowa, College of Education, Social and Educational Applications of Physics class in cooperation with the National Advanced Driving Simulator and students from The University of Iowa College of Engineering.

THE UNIVERSITY OF IOWA

Standards and Benchmarks

This curriculum assists in meeting the following standards and benchmarks:

		NGSS STANDARDS										IOWA CORE STANDARDS								
	Lesson Plan:	X:MS-PS 2-2	X:MS-PS 2-4	X:MS-PS 2-5	X:MS-PS 3-1	X:MS-PS 3-4	X:MS-PS 2-3	X:MS-PS 2-1	D:MS-PS 3-5	D:MS-PS 3-1	D:MS-PS 2-2.A	WHST.6-8.10	WHST.6-8.1	6.EE.B.6	6.EE.C.9	SL.8.4	SL.8.3	SL.8.2	SL.8.1	S.6-8.PS.3
UNIT 1	On the Move	X			X	X														X
UNIT 1	Graphing Complex Motion	X			X	X														X
UNIT 1	Driving				X	X					X									X
UNIT 2	Factors that Affect Motion		X					X	X	X		X	X	X	X					X
UNIT 2	Simulation Driving Day	X	X	X			X	X								X	X	X	X	X
UNIT 2	Finalizing Friction	X	X	X			X	X								X	X	X	X	X

		NGSS STANDARDS								
	Lesson Plan:	P:MS-PS 2-1	P:MS-PS 2-2	P:MS-PS 3-5	C:MS-PS 2-1	S:MS-PS 3-1	S:MS-PS 2-4	S:MS-PS 2-5	S:MS-PS 2-2	S:MS-PS 3-4
UNIT 1	On the Move				X			X	X	
UNIT 1	Graphing Complex Motion					X				X
UNIT 1	Driving							X	X	
UNIT 2	Factors that Affect Motion			X			X	X		
UNIT 2	Simulation Driving Day	X	X				X		X	
UNIT 2	Finalizing Friction	X	X				X		X	

Key

NGSS:
D= Disciplinary Core Ideas
X= Cross Cutting Concepts
S= Science and Engineering Practices
C= Constructing Explanations and Designing Solutions
P= Performance Solutions

Iowa Core

Science:

- S.6–8.PS.3:
    - Essential Concept and/or Skill: *Understand and apply knowledge of motions and forces.*
        - The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.
        - An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.
    - 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 will cause changes in speed or direction of an object's motion.

Comprehension and Collaboration:

- SL.8.1:
    - Engage effectively in a range of collaborative discussions (one–on–one, in groups, and teacher–led) with diverse partners on *grade 8 topics, texts, and issues,* building on others' ideas and expressing their own clearly.
- SL.8.2:
    - Analyze the purpose of information presented in diverse media and formats (e.g., visually, quantitatively, orally) and evaluate the motives (e.g., social, commercial, political) behind its presentation.
- SL.8.3:
    - Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identifying when irrelevant evidence is introduced.

Presentation of Knowledge and Ideas:

- SL.8.4:
    - Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well–chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics:

- 6.EE.C.9:
    - Use variables to represent two quantities in a real–world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation.

- 6.EE.B.6:
    - Use variables to represent numbers and write expressions when solving a real–world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.

Literacy

- WHST.6-8.1:
    - Write arguments focused on discipline–specific content.
- WHST.6-8.10:
    - Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline–specific tasks, purposes, and audiences.

NGSS

Disciplinary Core Ideas:

- MS-PS2-2.A:
    - All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.
- MS-PS3-1:
    - Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.
- MS-PS3-5:
    - When the motion energy of an object changes, there is inevitably some other change in energy at the same time.

Cross-Cutting Concepts:

- MS-PS2-2:
    - Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.
- MS-PS3-1:

  - Construct and interpret graphical displays of data to describe relationships of kinetic energy to the mass of an object and to the speed of an object.
- MS-PS 3-1, 3-4:
  - Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.
- MS-PS 3-4:
  - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- MS-PS 3-1 :
  - Construct and interpret graphical displays of data to identify linear and nonlinear relationships.
- MS-PS2-3, MS-PS2-5:
  - Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- MS-PS2-1, MS-PS2-4:
  - Models can be used to represent systems and their interactions such as inputs processes and outputs and energy and matter flows within systems.
- MS-PS2-2:
  - Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

<u>Science and Engineering Practices:</u>

- Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
- MS-PS2-2:
  - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- MS-PS 2-5:

  - Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.
- MS-PS2-4:
  - Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
- MS-PS2-2, MS-PS2-4:
  - Science knowledge is based upon logical and conceptual connections between evidence and explanations.

Constructing Explanations and Designing Solutions:

- Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.
- MS-PS 2-1:
  - Apply scientific ideas or principles to design an object, tool, process or system.

Performance Expectations:

- MS-PS3-5:
  - Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
- MS-PS2-2:
  - The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- MS-PS2-1:
  - For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).

Unit 1

Graphing Interpretation Competition

Goals:

To give students the skills to analyze and construct graphs (position vs. time, velocity or speed vs. time, acceleration vs. time, and direction vs. time).

Justification:

Students are often introduced to graphs, but according to teachers consulted, students rarely have the ability to fully analyze and describe them.

Graphical interpretation is needed in many professions, day-to-day life, and is seen on many standardized tests.

By introducing students to graphing early, they will be given the opportunity to improve graphing skills throughout middle and high school.

Lesson One: On the Move

Grade level: 6-8

Expected length of lesson: 45 minutes

Overview:

Introduction to graphing motion starting with probes to discuss misconceptions. An activity titled "On the Move: Velocity Activity" follows the probes to engage students in kinesthetic learning. The activity produces data that are graphed. Speed and acceleration are calculated based on the data acquired.

Standards and/or benchmarks:

NGSS:

Disciplinary Core Idea:

- MS-PS2-2:
  - All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

Science and Engineering Practices:

Planning and Carrying Out Investigations

- MS-PS2-2:
  - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- MS-PS2-5:
  - Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.

Constructing Explanations and Designing Solutions

- MS-PS2-1:
  - Apply scientific ideas or principles to design an object, tool, process or system.

Cross-Cutting Concept:

Scale, Proportion, and Quantity

- MS-PS3-1, MS-PS3-4:
  - Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Iowa Core:

- S.6–8.PS.3
  - Essential Concept and/or Skill: Understand and apply knowledge of motions and forces.
  - The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph

Learning Goals:

Students will understand:

- Graphs do not directly represent the motion; addresses the “What You See Is What You Get (WYSIWYG)” issue.
- The relationship of position to velocity and acceleration.

Learning Performances:

Students will be able to:

- Collect data to generate graphs.
- Generate graphs:
  - Position vs. time
  - Speed vs. time
  - Acceleration vs. time.
- Identify the motion of the object.

Materials:

- Following Jack Part II
    - Probe teacher guide
- Go Cart Test Run
    - Probe teacher guide
- *On the Move: Velocity Activity* worksheet
    - *On the Move: Velocity Activity* Teacher notes
- Masking tape
- Timer
- Meter stick
- Motion story worksheet

Safety:

Consider location during *On the Move: Velocity Activity*; walking and running is required.

Critical Thinking Question:

What story are the graphs are telling us?

Students' Ideas:

The students should have some familiarity with distance, direction, speed and/or velocity, acceleration and what those mean scientifically. Students will likely have misconceptions about graphing.

Main Lesson:

1. Teachers present the lesson's critical thinking question: What story are the graphs telling us?
2. Hand out Go Cart Test Run probe and instruct students to complete it.
3. After students are done with the probe sheets, instruct students to form small groups (2~3 students).
    a. Students discuss reasoning for their answers.
    b. This is to engage students who are most comfortable with talking in smaller groups.

4. Instruct students to have a class discussion sharing thoughts from the small group discussion.
    a. Whole class discussion reveals class misconceptions.
5. Instruct students to start *On the Move: Velocity Activity*.
    a. Use a jigsaw activity to allow students to explain different parts of the instructions to their peers.
    b. Model the experiment set up. (Applying tape, walking, running etc.)
    c. Model how to create and/or fill out the table.
6. Pair students to conduct the activity.
    a. Monitor progress.
    b. Ensure data table completion.
7. After data is collected, instruct students to return to seats and begin graphing.
    a. Instruct students work individually or in pairs.
    b. Monitor the graphing process, and if necessary, model how to fill out the graphs.
    c. Collect worksheets.
8. Hand out Motion Story Worksheet Homework:
    a. Read instructions out loud.
    b. Go over the worksheet example.
    c. Stories will include 3-5 events such as: stopping for a light, changes in speed, turning left or right, etc.
    d. The length of the trip can be adjusted to meet student needs

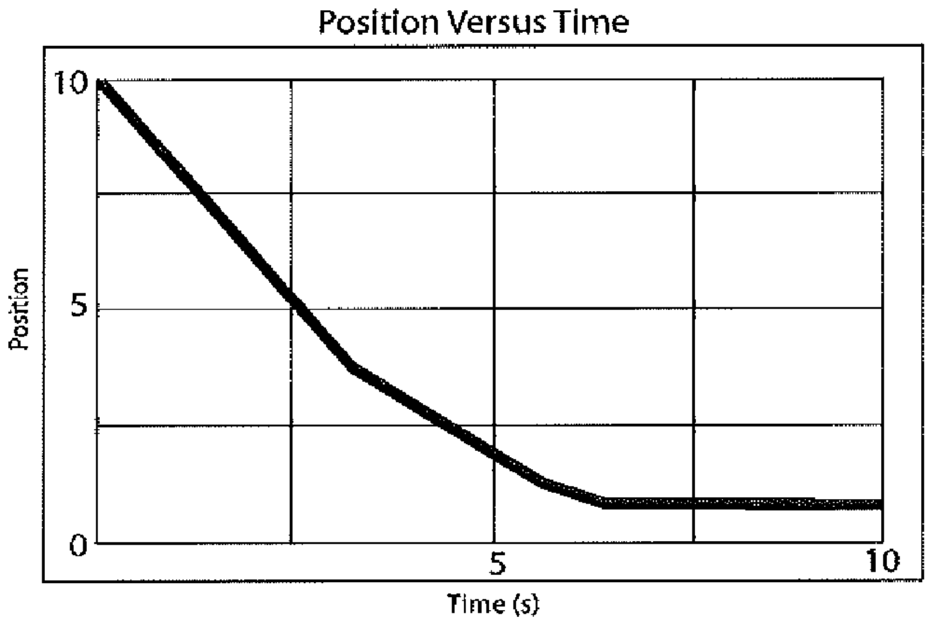
Differentiation:

- Students should be grouped appropriately.
- Activity worksheet differentiation is described in section five *On the Move: Teacher Notes*.
- Homework can be modified with maps and drawing instead of writing long descriptions.

Assessment:

The assessment is *On the Move: Velocity Activity*. Rubric is found in section four of *On the Move: Teacher Notes*.

Go-Cart Test Run Probe



Jim and Karen have built a go-cart. They take their go-cart for a test run and graph its motion. Their graph is shown above. They show the graph to their friends. This is what their friends say:

Bob: "That was a steep hill! You must have been going very fast at the bottom."

Claire: "I think you were going fast at first, but then you were moving slowly at the end."

Karl: "I think you were moving quickly, then slowed down to a stop at the end."

Mary: "It looks like you were going downhill and then the road flattened out."

Circle the name of the friend you think best describes the motion of the go-cart based on the graph. Explain why you agree with that friend.

____

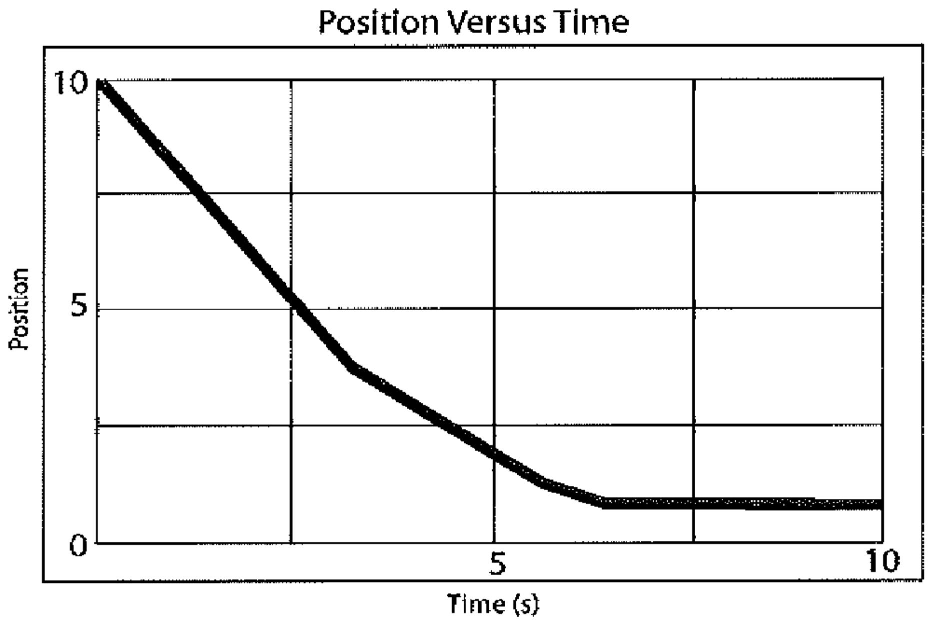
____

____

Revised version of probe 5 Go-Cart Test Run in Vol. 1 of Uncovering Student Ideas in Physical Science (Keeley & Harrington, 2010)

Go-Cart Test Run Probe Teacher Notes

Purpose



The purpose of this probe is to examine how students interpret a graphical representation of motion. The probe is designed to reveal whether students interpret a motion graph pictorially or mathematically.

Related Concepts

Clock readings, constant speed, graph, position, time, time intervals, speed, and uniform motion

Explanation

Karl has the best answer: "I think you were moving quickly, then slowed down to a stop at the end." The speed of the go-cart is related to the slope of the line on the graph. Between 0 and 3 seconds, the go-cart is moving at a constant speed. Between 3 and 6 seconds, the go-cart is still moving at a constant speed, but slower than the previous interval. Between 6 and 7 seconds, the go-cart is moving at a slower speed. From 7 seconds on, there is no change in position; the go-cart has stopped.

A graph can also be interpreted by the slope of the lines. A straight line with a steep slope indicates constant motion at a greater speed than a straight line with a more gradual slope. When the line on a graph is horizontal, that means that as time goes by, the position of an object is not changing. The horizontal line on this graph means that the go-cart stops at the end of the motion.

Administering the Probe

This probe is appropriate for middle school students and high school students. You may adapt the probe by eliminating the answer choices and having students "tell the story" indicated by the graph. For students who may be unfamiliar with position versus time graphs, it may be helpful to describe the y axis as the milepost or distance marker.

Suggestions for Instruction and Assessment

- Provide multiple opportunities for students to construct and interpret graphs, so you can see what students understand or misunderstand about graphs and graphing.
- Provide students with different types of motion graphs, and have them make up stories about what the graphs show. Encourage discussions about the accuracy of their stories. Do the stories accurately reflect the information on the graphs? This strategy, popular in mathematics classes, can help students overcome the tendency to view graphs as a literal picture.
- Use motion detectors and students' real movements to help students construct a visual and kinesthetic understanding of position versus time. MBLs (microcomputer-based laboratories) are known to improve the development of students' abilities to interpret graphs. MBLs are particularly effective in helping middle school students understand that a graph is not a literal picture.
- Most middle school science curricula use distance versus time graphs instead of position versus time graphs. Although both types of graphs can be interpreted in the same way, teachers should help students understand the distinction between distance and position. In some textbooks, distance may mean distance traveled whereas position refers to the location of an object. In some special cases (such as when the motion starts at zero position) these terms mean the same thing. However, to avoid confusion, physics teachers tend to use position, which has a well-defined meaning.

Revised version of probe 5 Go-Cart Test Run Teacher Notes in Vol. 1 of Uncovering Student Ideas in Physical Science (Keeley & Harrington, 2010)

On the Move: Velocity Activity

Name: ______________________ Date: _____________

Group Mates: ___________________________________

Materials:

- Meter stick
- Masking tape
- Timer

Directions:

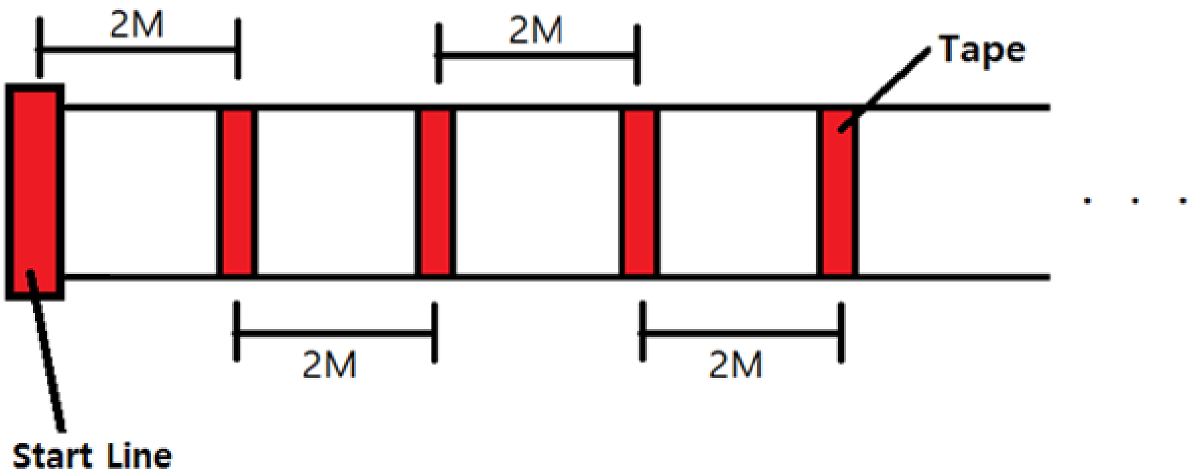
In small groups you will conduct an experiment to create a position vs. time graph.

1. With masking tape, make a start line on the floor. Make sure it is visible to everyone.

2. Measure two meters from the start line. Place another strip of masking tape.

3. Have total of six masking tapes representing each two meter mark. The total distance marked off should be 12 meters.

4. After setting up your experiment, it should look something like this:



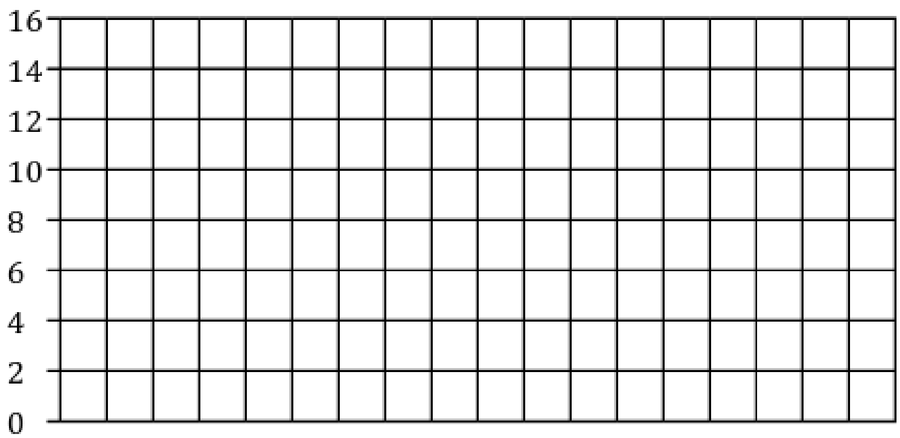
5. Start walking from 0-6 meters. Then, increase your speed (run) immediately after 6 meters and maintain a faster constant speed (same running speed).

Data:

Distance (m)	Time (seconds)
0	0

2	
4	
6	
8	
10	
12	

Graph (fill in appropriate increments for the time axis):



Velocity Calculations and Questions:

1. Calculate velocity.

   a. Determining the velocity between 0-2 meters.

      1. What is the change in distance from the start to the 2-meter mark?

      2. What is the change in time from the start to the 2-meter mark?

3. Calculate velocity as the change in distance (calculated in step 1) over the change in time (calculated in step 2).

b. Repeat this process for each increment (2-4, 4-6, 6-8, etc.) and fill in the table.

Distance Interval	**Change in Distance (m)**	**Change in Time (seconds)**	**Velocity (m/s)**
0m – 2m			
2m – 4m			
4m – 6m			
6m – 8m			
8m – 10m			
10m – 12m			

2. Did the velocity change over the 12 meter distance? Why do you think it changed or stayed the same?

___

___

3. What do you think would happen to the velocity if you decreased your speed over the 12-meters?

___

4. Draw a graph for velocity vs. time from the data you calculated in step 1.

Acceleration Calculations and Questions:

1. There is a change in speed between 6 meters to 8 meters. Whenever there is a change in speed or direction vs. time, it is called **acceleration**.

2. Calculate acceleration.

    a. Determining the acceleration between 6-8 meters.

        1. What is the change in velocity from the 6 to the 8-meter mark that you calculated in the table in the previous section (velocity calculations and questions)?

        2. What is the change in time from the 6 to the 8-meter mark?

        3. Calculate acceleration as the change in velocity (calculated in step 1 above) divided by the change in time (calculated in step 2 above).

    b. Repeat this process for each increment (2-4, 4-6, 6-8, etc.) and fill in the table.

Velocity Interval	**Change in Velocity (m/s)**	**Change in time (seconds)**	**Acceleration (m/s^2)**

3. What will happen to the acceleration if the speed increases more after 12m? Explain why.

____

____

4. Draw a graph for acceleration vs. time.

On the Move: Teacher Notes

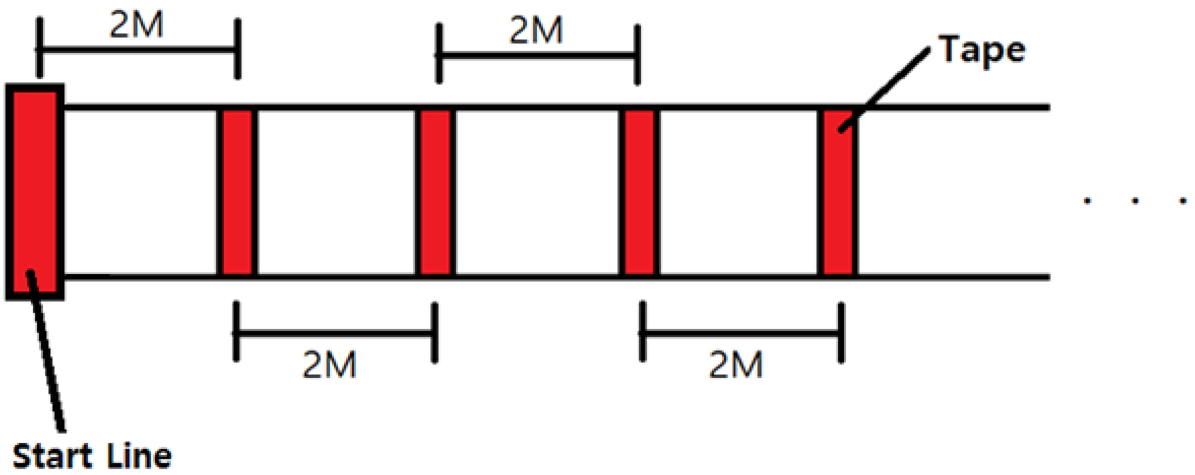
Groups of 2-4 are recommended.

Materials:

- Timer
- Tape
- Meter stick

Directions:

1. Setting up the experiment:
    a. Students will follow the instructions that were provided on activity to set up the experiment.
    b. On the ground tape 2-meter marks for 12 meters (see diagram) there will be 7 tape marks total.



2. Group students per your discretion.
3. One group member will physically walk and run per instructions.
    a. A wheelchair bound or physically challenged student who is capable of multiple speeds may also choose to participate.
    b. Remaining group members will use stopwatches and time when the tape marks are crossed.
4. Calculations

a. The calculation for velocity is the change in distance (m) over the change in time (seconds):

$$\frac{\Delta d}{\Delta t} = \frac{d_2 - d_1}{t_2 - t_1}$$

1. For this calculation, each distance interval will be 2 meters.

b. The calculation for acceleration is the change in velocity (m/s) over the change in time (seconds):

$$\frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1}$$

1. The *velocity interval* (in the acceleration calculations and questions section) should be determined from the calculated velocities in the previous table.
2. The *change in time* column for the acceleration table should be calculated from the *change in time* column in the velocity table (in the velocity calculations and questions section), not from the distance table (in the data section).

5. Graphing
   a. When the students graph the distance vs. time data, ensure that each axis is given a label and units. Students may need some help determining appropriate intervals for the x-axis (time).
   b. When graphing the velocity data, use the velocities calculated in the *velocity calculations and questions* section. For the time, use the times in the *data* section (distance vs. time collected by the student) starting with the time for 2m.
      1. Velocity is in m/s; therefore, the time used for plotting is the end time of the interval used to calculate the velocity (the time from 0-2m).
   c. When graphing the acceleration data, use the acceleration calculated in the *acceleration calculations and questions* section. For the time, use the times in the *data* section (distance vs. time collected by the student) starting with the time for 4m.
      1. Acceleration is in m/s^2; therefore, the time used for plotting is the end of the time interval used to calculate the acceleration (two time intervals: the times from 0-2m and 2-4m).
   d. Have the students discuss what they observed during the experiment and how that relates to what they see on the graph.
6. Collect filled out worksheet from the students and grade based on the following rubric:

Item/Score	**0**	**1**	**2**	**3**

Graph	Students did not attempt to plot the data, label the axes or determine the best interval for time.	Students had numerous plotting, labeling, or interval errors in their graphs.	Students had some plotting, labeling, or interval errors in their graphs.	Students had few or no errors for each graphs.
Calculation	Students did not show their work and had incorrect answers.	Students had the correct answer but did not show their work.	Students did not have the correct answer but showed their work and the processes or formulas were correct.	Students had the correct answer and showed their work. Their processes or formulas were correct.
Explanations	Students did not write any response.	Student wrote a non-scientific response.	Students wrote a response with an incomplete scientific explanation.	Students wrote a response with a complete scientific explanation.

7. Differentiation
   - For special education students, label the axes and determine appropriate time intervals for them to plot their data.
   - For ELL students, model the activity, calculations, and graphing.
   - For high achievers, use tables without headers and graphs without any labels on the axes.

Motion Story Worksheet

Name: ______________________ Date: _____________

Describe a trip you took or would like to take in or around your neighborhood. For example, you may write the events of a bike ride to a friend's house, your walk to school, or the drive to a grocery store. Use a term from each of the bullet points at least once when describing your trip:

- speeding up/sped up
- slowing down/slowed down
- constant speed
- stop/stopping/stopped
- turn/turning/turned (including direction - left or right)

Include approximate times and distances for each part of your trip. You may describe your trip as a written paragraph, a table, or a list with bullets or numbers. It may be helpful to draw or print a map (with a program like *Map My Route* or *GoogleMaps*) of your route.

Example:

On my way to my friend's house, I first walked at ***constant speed*** out my door and down the driveway for about 15 feet in about 10 seconds. I ***turned right*** at the sidewalk walking one step (about 3 feet) in about 1 second then walked ***at a constant speed*** for 3 blocks (about 300 feet) in about 2 minutes. I ***turned left*** walking one step (about 3 feet) in about 1 second and ***stopped*** to wait for about 1 minute for the light to change. I *sped up* in several steps (about 10 feet) in about 5 seconds and walked *at constant speed* for 3 blocks (about 300 feet) in about 2 minutes. I *turned left* in one step (about 3 feet) toward my friend's house in about 1 second and *slowed down* for about 15 feet in about 10 seconds until I *stopped* at her door.

Lesson Two: Graphing Complex Motion

Grade level: 6-8

Expected length of lesson: Approximately 45 to 60 minutes

Overview:

For the second day, students use their homework to evaluate position (distance), speed, acceleration and direction for complex motion. Students analyze the trip they wrote for their homework from the perspectives of distance, speed, acceleration, and direction to be used to graph the motion. Teacher asks students to draw a data set consisting of 4 graphs by the end of class: (1) distance vs. time, (2) speed vs. time, (3) acceleration vs. time, and (4) direction vs. time. Students are then expected to analyze a data set of a new situation and determine the trip events in order for complex motion. Students are in groups of 4 and roles for simulator are assigned.

Standards and/or benchmarks:

NGSS:

Disciplinary Core Ideas:

Forces and Motion

- MS-PS2-2:
  - All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

Cross-Cutting Concepts:

Scale, Proportion, and Quantity

- MS-PS3-1, MS-PS3-4:
  - Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Science and Engineering Practices:

Planning and Carrying Out Investigations

- MS-PS3-4:
  - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.

Analyzing and Interpreting Data

- MS-PS3-1:
  - Construct and interpret graphical displays of data to identify linear and nonlinear relationships.

Iowa Core:

- S.6–8.PS.3
  - The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

Learning Goals:

Students will understand:

- Graphs depicting motion are related: (1) distance vs. time, (2) speed vs. time, (3) acceleration vs. time, and (4) direction vs. time.

- The relation of variables to time graphically.
- Graphs depicting complex motion are more complex.
- Multiple graphs are used to depict complex motion.

Learning Performances:

Students will be able to:

- Write their trip from the perspective of (1) distance, (2) speed, (3) acceleration, and (4) direction.
- Use the write up their trip from each perspective to generate a graph for each (a data set).
- Find missing events of the trip in one graph that are represented in another graph.
- Analyze a new data set to determine the motion.

Materials:

- Completed homework assignment
- Homework teacher notes
- Graph paper
- Project data set

Safety:

NA

Critical Thinking Question:

What story are the graphs telling us?

Student Ideas:

Allow student to write the stories in whatever way makes the most sense to them (paragraph, bullets, numbered list, tabular, etc.).

Main Lesson:

1. Instruct students to take out their homework assignments.

   a. If students' assignments are incomplete or less detailed, provide additional help in the next steps.
   b. If students did not complete the homework, pair them with an appropriate student who has finished the assignment.
2. Ask students where they went and how many drew maps to help them.
   a. If students have similarities on the type of trip they wrote about, grouping may be used for the next steps to allow students to help each other.
3. Instruct students to identify their starting and ending points on a new piece of paper.
4. Instruct students to write their trip from 4 different perspectives:
   a. distance from the starting point
   b. speed
   c. acceleration
   d. direction from the starting point
5. Provide instructions for writing each perspective from the starting point to the ending point.
   a. Chunk the instructions for each perspective.
   b. Consider how students organize the information (table format, bullets, or numbering the steps).
   c. Either use an example or one of the students' trips to model how to write the trip from each perspective. An example is provided in the teacher notes accompanying the homework.
   d. Monitor while students are writing their trips from each perspective to ensure that all the necessary details are included.
6. Explain to students how to make each graph after the story is written from each perspective.
   a. As a whole class, ask students to determine the variables in each perspective. They need to identify time as one variable in each.
   b. As a whole class, ask students to identify where each variable goes on the graph. Ask them to explain their thinking. Students may not use the terms dependent and independent variable, but they should be able to reason that time goes on the bottom from instruction the day before.
   c. Chunk the instructions and model how to generate a graph for each perspective. Use an example or one of the students' trips.
   d. Emphasize the shape over exact values at this time.
   e. Monitor while students graph their trip from each perspective.
7. Pair students to review each other's work.
   a. Have the students compare the *originally* written trip to the graphs. It is not necessary to read the trip from each perspective.
   b. Allow students to change and improve their graphs.
8. After students are satisfied with their graphs, have a short discussion.
   a. Ask students if the graphs look how they expected them to.
   b. Ask students if there are any parts missing from the trip in one of the graphs (a change in direction is not seen in the other graphs, etc.).
   c. Ask students if all the graphs are necessary. It may help to ask if it is easy to determine the acceleration in the distance graph.
9. Have students turn in their paperwork (the homework, the four perspectives, and graphs).

10. While handing out the activity data set (a new set of graphs like the ones the students just generated), explain to the students they need to figure out the "trip" this time.
    a. Instruct students to determine three parts:
        1. What is happening?
            a. Speeding up or positive acceleration
            b. Slowing down or negative acceleration
            c. Constant speed or constant acceleration
            d. Stopping (constant position or distance)
            e. Turning left or right (changing direction where right is positive and left is negative).
        2. How long it takes in seconds. This needs to include the increment (e.g. for 20 seconds) and the total time when it starts and stops (e.g. at 80 seconds until 100 seconds).
        3. The value of the motion
            a. If the speed is constant, what that speed is.
    b. Model how to generate a table for the information using an example.
11. Explain to students that the table should be their best work because they are going to drive this trip on a simulator the next day.
    a. Describe the contest to them.
        1. The trip they write from the graphs is going to be driven on the simulator.
        2. Graphs from the simulator are going to be generated and they are going to compare them to the ones they were just handed.
        3. The winning group will be chosen by the students.
            a. The winner will be the group with the graphs that are closest to the originals.
            b. Get the students thinking about how they will pick the winner; what criteria will they use.
12. Select groups of 3 or 4 depending upon the number of students.
    a. Assign roles to the members of the groups. Depending upon the class, groups may assign roles themselves.
    b. Roles include
        1. Driver - Student driving the simulation.
        2. Manager - Student who determines the final driving trip and writes up the instructions to follow.
        3. Coach - Student who gives explicit instructions to the driver of what to do at each step of the driving simulation.
        4. Timer - Student who watches the on-screen timer to signal when the next step will occur.
    c. Emphasize the need to be collaborative for the best result.

Differentiation:

- Advanced learners can make a more complex trip and do not provide pre-labeled graphs or tables. Ensure they have used one of each: deceleration, complete stop, acceleration, constant speed, and direction.

- Special needs students can make a scenario with 3 events and should be given graphs with axes pre-labeled.
- For ELL students, adjust the requirements for more visual learning. Stress the terms distance, speed, acceleration, and direction.

Assessment:

- While monitoring the perspective writing and graphing ask individuals or groups probing questions.
- Collect the homework, perspectives, and graphs.

Motion Story Homework Teacher Notes

Individual work is recommended but small groups with similar trips may be used for students to help each other.

Materials:

- Graph paper

Directions:

1. The example on the next pages may be used as an example for instructing students on how to write their stories.
    a. This example may be handed out at your discretion.
2. Instruct students to rewrite their stories from each of four perspectives: distance, speed, acceleration, and direction.
    a. Provide instruction on how to do one of the perspectives.
    b. If the story is written in multiple units (both minutes and seconds or feet and miles), the rewritten stories will need to be converted to only one unit (either minutes or seconds, etc.).
    c. Allow students some time to struggle with figuring out the others before providing guidance.
    d. Use the example on the following pages as needed.
    e. Tables with more instructions may be provided for struggling students.
    f. Repeat for each of the other perspectives.

3. Instruct students to graph the stories from each of the four perspectives.
    a. Graphs with labeled axes may be provided for struggling students.
    b. Emphasis should be on the shape of the graphs and how they relate to each other rather than exact values.

Examples:

1. Writing the trip in different formats:

    a. In paragraph form:

    - On my way to my friend's house, I first walked at *constant speed* out my door and down the driveway for about 15 feet in about 10 seconds. I *turned right* at the sidewalk walking one step (about 3 feet) in about 1 second then walked at a *constant speed* for 3 blocks (about 300 feet) in about 2 minutes. I *turned left* walking one step (about 3 feet) in about 1 second and *stopped* to wait for the light to change for about 1 minute. I *sped up* in several steps (about 10 feet) in about 5 seconds and walked at *constant speed* for 3 blocks (about 300 feet) in about 2 minutes. I *turned left* in one step (about 3 feet) toward my friend's house in about 1 second and *slowed down* for about 15 feet in about 10 seconds until I *stopped* at her door.

    b. In bulleted or numbered form:

    - First walked at *constant speed* out my door and down the driveway for about 15 feet in about 10 seconds
    - I *turned right* at the sidewalk walking one step (about 3 feet) in about 1 second
    - Then I walked at a *constant speed* for 3 blocks (about 300 feet) in about 2 minutes
    - I *turned left* walking one step (about 3 feet) in about 1 second
    - Then I *stopped* to wait for the light to change for about 1 minute
    - I *sped up* over several steps (about 10 feet) in about 5 seconds
    - I walked at *constant speed* for 3 blocks (about 300 feet) in about 2 minutes
    - I *turned left* in one step (about 3 feet) toward my friend's house in about 1 second
    - Finally, I *slowed down* for about 15 feet in about 10 seconds until I *stopped* at her door.

    c. In tabular form:

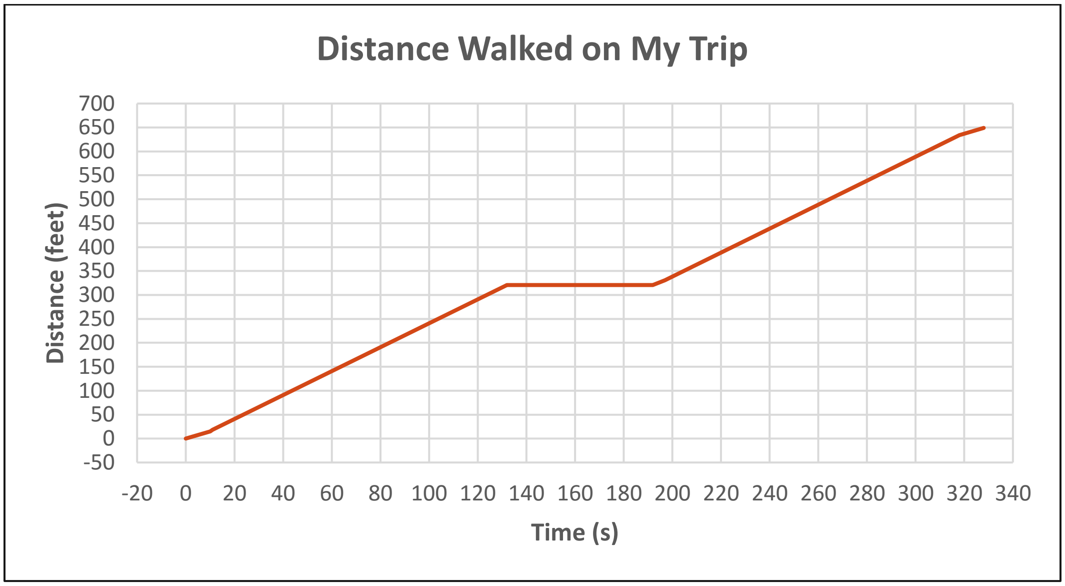
Action	**Approximate Distance**	**Approximate Time**
First walked at constant speed out my door and down the driveway	15 feet	10 seconds
I turned right at the sidewalk	1 step (3 feet)	1 second

Then walked at a constant speed	3 blocks (300 feet)	2 minutes (120 seconds)
I turned left	1 step (3 feet)	1 second
Then I stopped to wait for the light to change	0 feet	1 minute (60 seconds)
I sped up	Several steps (10 feet)	5 seconds
I walked at constant speed	3 blocks (300 feet)	2 minutes (120 seconds)
I turned left toward my friend's house	1 step (3 feet)	1 second
Finally, I slowed down until I stopped at her door	15 feet	10 seconds

2. Writing the trip from distance perspective:
    a. In bulleted form:
        - First walked at *constant speed* out my door and down the driveway for about 15 feet in about 10 seconds
        - I *turned right* at the sidewalk walking one step (about 3 feet) in about 1 second
        - Then I walked at a *constant speed* for 3 blocks (about 300 feet) in about 2 minutes
        - I *turned left* walking one step (about 3 feet) in about 1 second
        - Then I *stopped* to wait for the light to change for about 1 minute
        - I *sped up* over several steps (about 10 feet) in about 5 seconds
        - I walked at *constant speed* for 3 blocks (about 300 feet) in about 2 minutes
        - I *turned left* in one step (about 3 feet) toward my friend's house in about 1 second
        - Finally, I *slowed down* for about 15 feet in about 10 seconds until I *stopped* at her door.
    b. An example table and graph:

Time (seconds)	Total Time (seconds)	Distance (feet)	Total Distance (feet)
0	0	0	0
10	10	15	15
2	11	3	18
120	131	300	318
2	132	3	321
60	192	0	321
5	197	10	331

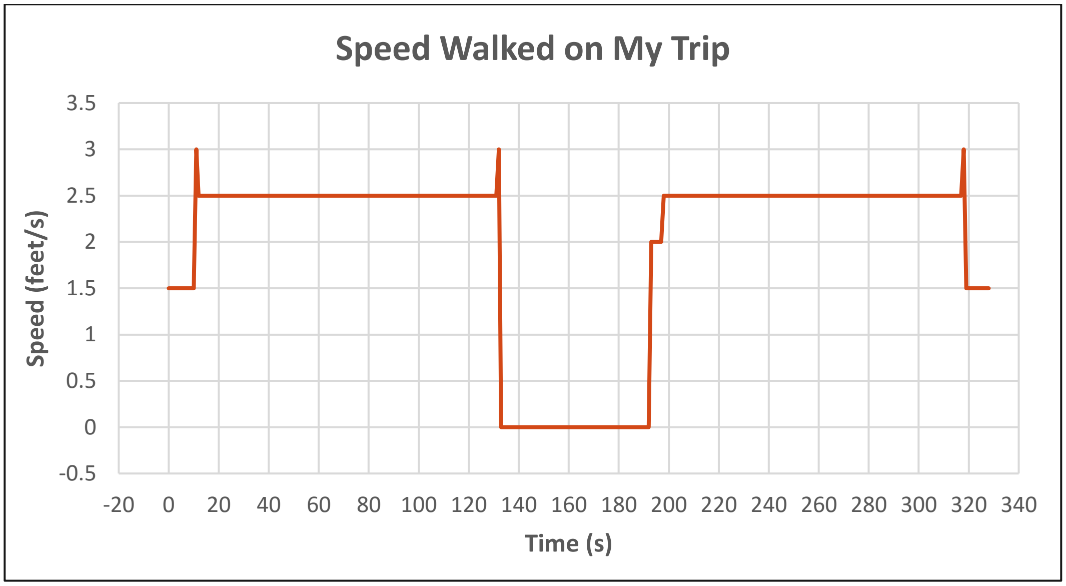
120	317	300	631
1	318	3	634
10	328	15	649



3. Writing the trip from speed perspective:
   a. In bulleted form:
      - First walked at *constant speed* out my door and down the driveway for about 15 feet in about 10 seconds
      - I *maintained this speed* when I turned right at the sidewalk walking one step (about 3 feet) in about 1 second
      - Then I continued to walk at a *constant speed* for 3 blocks (about 300 feet) in about 2 minutes
      - I *maintained this speed* when I turned left walking one step (about 3 feet) in about 1 second
      - Then I *decreased my speed suddenly before stopping* to wait for the light to change for about 1 minute
      - I *sped up* over several steps (about 10 feet) in about 5 seconds
      - I walked at *constant speed* for 3 blocks (about 300 feet) in about 2 minutes
      - I *maintained my speed* while I turned left in one step (about 3 feet) toward my friend's house in about 1 second
      - Finally, I *slowed down* for about 15 feet in about 10 seconds until I *stopped* at her door.
   b. An example table and graph:

Time (seconds)	Speed (feet/s)

0	0
0-10	1.5
10-11	3
11-131	2.5
131-132	3
132-192	0
192-197	2
197-317	2.5
317-318	3
318-328	1.5

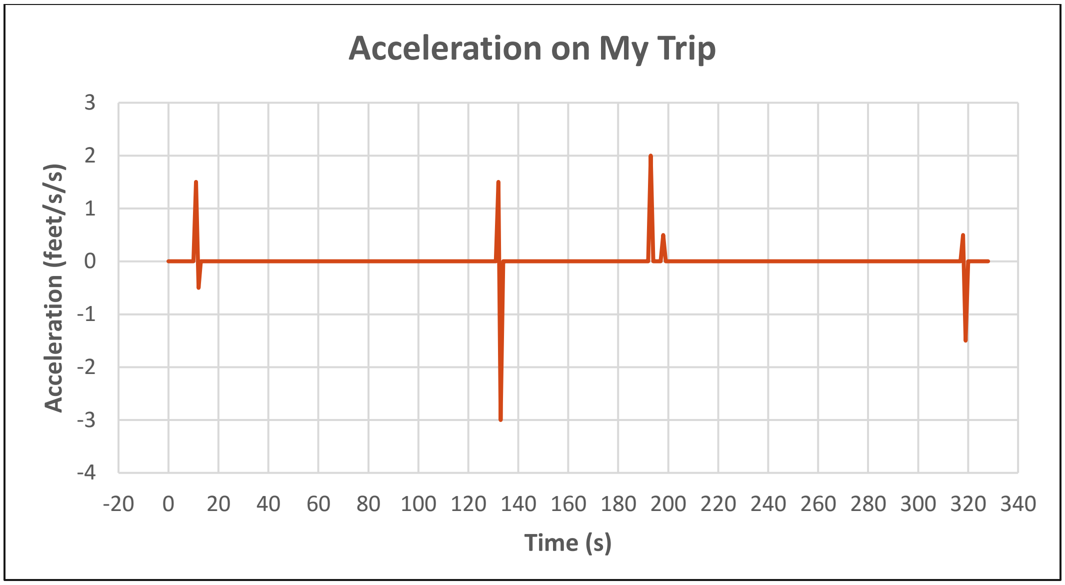


4. Writing the story from acceleration perspective:
   a. In bulleted form:
      - First I walked *with no acceleration* out my door and down my driveway (about 10 seconds)
      - I turned right *while accelerating slightly* at the sidewalk (about 1 second)
      - Then walked *with no change in acceleration* for about 3 blocks (about 2 minutes)
      - I turned left *while accelerating slightly* (about 1 second)
      - Then I *quickly decelerated* (about 2 seconds) to a stop (about 1 minute)
      - I *accelerated to reach constant walking speed* (about 5 seconds)
      - I walked *with no acceleration* for about 3 blocks (about 2 minutes)

- I turned left *while accelerating slightly* (about 1 second)
- Finally, I *decelerated slowly* (about 10 seconds) until I stopped at her door.

b. An example table and graph:

Time (seconds)	Acceleration (feet/s/s)
0	0
0-10	0
10-11	1.5
11-12	-0.5
12-131	0
131-132	1.5
132-133	-3
133-192	0
192-193	2
193-197	0
197-198	0.5
198-317	0
317-318	0.5
318-319	-1.5
319-328	0



5. Writing the trip from direction perspective:

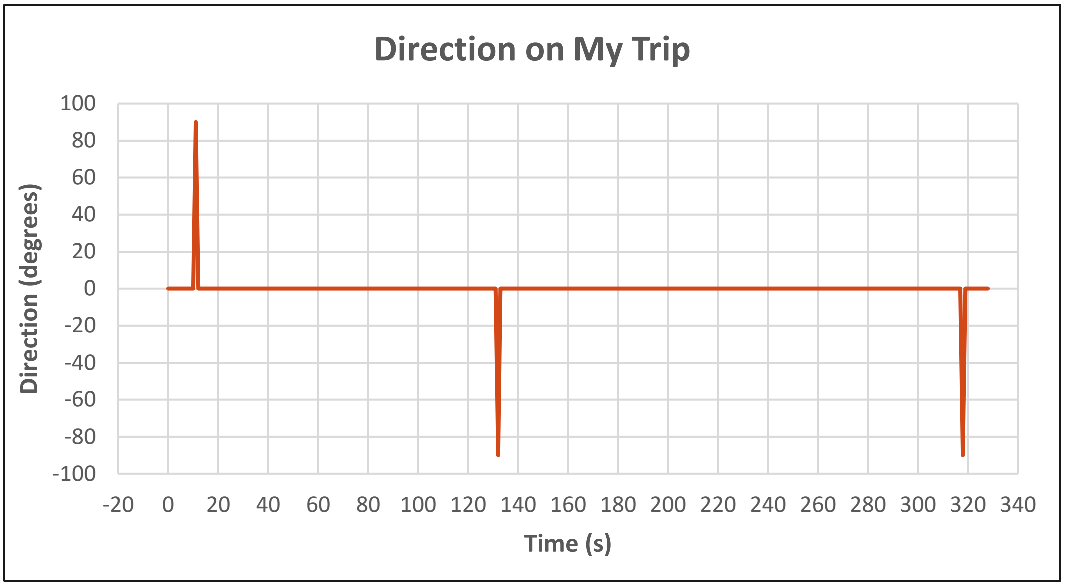
   a. In bulleted form:

      - First I walked **straight** out my door and down my driveway (about 10 seconds)
      - I **turned right** at the sidewalk (about 1 second)
      - Then walked **straight** for 3 blocks (about 2 minutes)
      - I **turned left** (about 1 second)
      - Then I stopped **without turning** to wait for the light to change (about 1 minute)
      - I sped up walking **straight** (about 5 seconds)
      - I walked **straight** for 3 blocks (about 2 minutes)
      - I **turned left** toward my friend's house (about 1 second)
      - Finally, I slowed down while walking **straight** (about 10 seconds) until I stopped at her door.

   b. An example table and graph:

Time (seconds)	Direction (degrees)
0	0
0-10	0
10-11	90
11-131	0
131-132	-90
132-317	0

317-318	-90
318-328	0

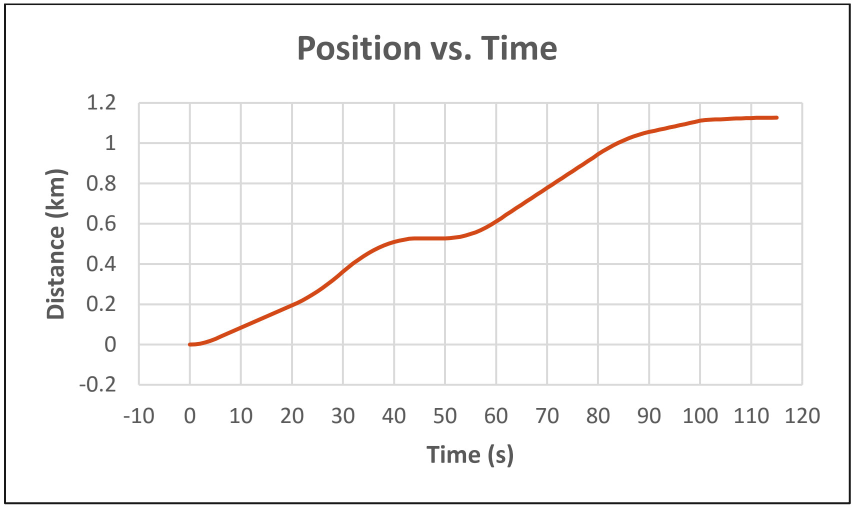


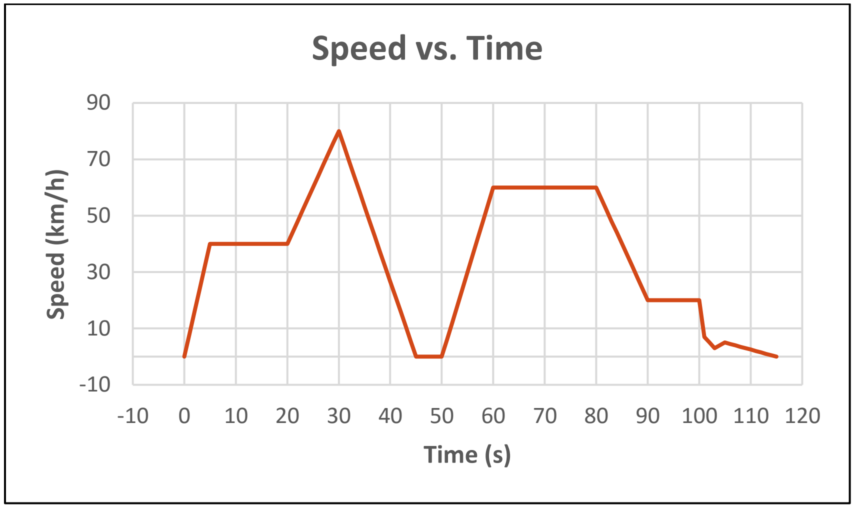
6. These stories can be used by struggling students as additional practice for graphing. Other adjustments may be made to challenge higher performing students and assist ELL students.
7. The basic skills of this task should not be altered in order to interpret the graphs for the simulation activity on day 3.
8. Students will need help with graphing. Provide examples of:
    a. Graph titles
    b. Labeling axes - both title and units
    c. Axes increments
9. For the speed and acceleration graphs, use the same time intervals as in the distance graph. Students can draw the basic shape of the graph. The velocity and acceleration calculations from the *On the Move* activity and teacher notes may be used to calculate actual values, if desired.
10. Grade the homework with the following rubric:

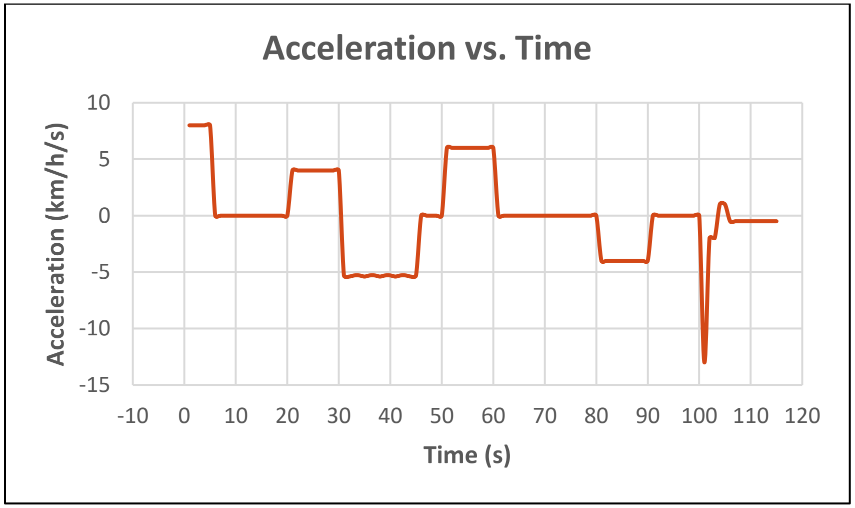
Item/Score	0	1	2	3
Trip Rewrites	Students did not attempt to	Students attempted to	Students attempted to	Students wrote the trip from all

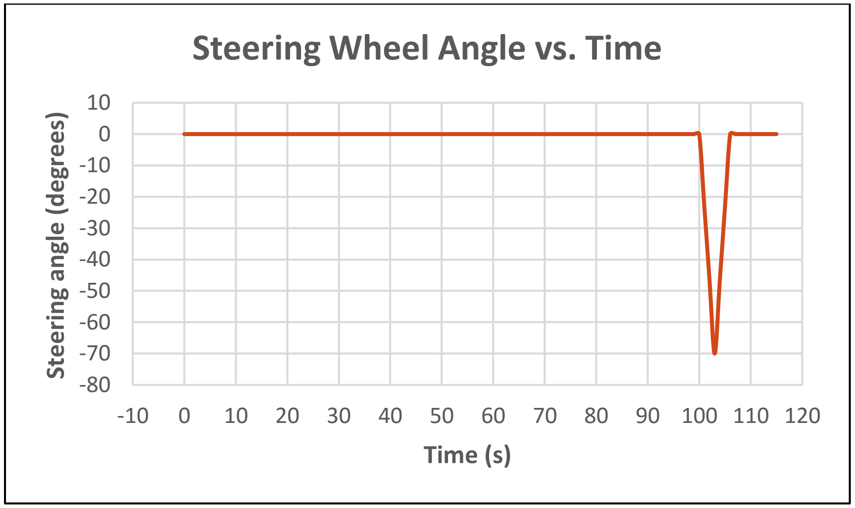
(from each perspective)	write trip from each perspective.	write one or two perspectives, but not all. Student did not include all the necessary details.	write the trip in all three perspectives. Most of the necessary details were included.	three perspectives with few errors. Most or all of the necessary details were included.
Graphs	Students did not attempt to plot the data, label the axes or determine the best interval for time.	Students had numerous plotting, labeling, or interval errors in their graphs.	Students had some plotting, labeling, or interval errors in their graphs.	Students had few or no errors for each graphs.

Driving Simulation Graphs Homework









Write out a driving plan that describes the motion of the car that is represented in the above graphs. Compare your plan with your group members and decide on a final plan to use with the simulator.

Lesson Three: Simulation Driving Day

Grade level: 6-8

Expected length of lesson: Two days, approximately 90 minutes

Overview:

On the third day, groups should finalize their driving plan before driving the simulator to replicate the graphs given to them the prior day. Afterwards, NADS generated graphs are compared to the homework graphs. An assessment will follow the NADS simulation and graph comparison.

Standards and/or benchmarks:

NGSS:

<u>Disciplinary Core Idea:</u>

Forces and Motion

- MS-PS2-2:
  - All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

<u>Cross-Cutting Concepts:</u>

- MS-PS3-1, MS-PS3-4:
  - Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

<u>Science and Engineering Practices:</u>

Planning and Carrying Out Investigations

- MS-PS2-2:
  - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- MS-PS2-5:

- Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.

Iowa Core:

- S.6–8.PS.3
  - Essential Concept and/or Skill: *Understand and apply knowledge of motions and forces.*
    - The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

Learning Goals:

Students will understand:

- How position vs time, speed vs time, acceleration vs time and steering (or direction) vs time are related
- Multiple graphs are necessary to know the whole story of complex motions.

Learning Performances:

Students will be able to:

- Generate a driving plan from the 4 graphs provided.
- Compare simulation graphs to activity graphs.
- Compare simulation graphs between groups.
- Decide the criteria to pick a winner of the driving contest.

Materials:

- Activity graphs
- NADS simulator
- Describing Motion and Position Using Graphs (Assessment Activity)
- Assessment Key and Rubrics

Safety:

Make sure students with a history of motion sickness do not drive the simulator.

Critical Thinking Question:

What story are the graphs are telling us?

Student Ideas:

Students will devise a method to translate a graphical representation of motion into a real-world complex motion using the simulator.

Main Lesson:

At the end of the second lesson plan, students were given the four activity graphs to analyze to create a list of motion segments from information on the graphs. Roles for each group member were also assigned (timer, driver, manager, coach).

1. Students will gather in assigned groups of 3-4, with member roles already assigned.
   a. Students should compare the trips they wrote from the graphs.
   b. An example of the trip that may be used to check the work of the students:

Action	Details	Total Time (seconds)
Accelerate	Go from 0 km/h to 40 km/h in 5 seconds	5
Constant speed	Continue at 40 km/h for 15 seconds	20
Accelerate	Go from 40 km/h to 80 km/h in 10 seconds	30
Decelerate	Go from 80 km/h to 0 km/h in 10 seconds	40
Full stop	Stop for 10 seconds	50
Accelerate	Go from 0 km/h to 60 km/h in 10 seconds	60 (1:00)
Constant speed	Continue at 60 km/h for 20 seconds	80 (1:20)
Decelerate	Go from 60 km/h to 20 km/h in 10 seconds	90 (1:30)
Constant speed	Continue at 20 km/h for 10 seconds	100 (1:40)
Turn	Turn left	105 (1:45)

   c. The manager should determine the final trip for the group.
      1. This will be the instructions the group uses to drive on the simulator.

2. When the trips are finalized, have the class decide the criteria that will determine the winner.
    a. Examples of criteria include: accelerating at the right times, accelerating at the correct rate, maintaining correct speeds, turning the correct direction, etc.
3. Explain that each group will have one attempt to drive the simulation to generate graphs as close to the given activity graphs as possible.
    a. If time permits, groups may have the ability to drive more than once.
4. Choose how to decide the order of groups.
    a. Groups should not be allowed to watch others drive the simulator.
5. Graphs will be generated by the simulation program after all groups have finished their simulation.
    a. The ideal graphs (from the homework) will be the black line on the graph.
    b. Each graph will contain all of the trials from the groups in different colors.
    c. Groups will not know what color they are until after the winner is decided.
    d. Winners will be given prizes brought by NADS (pencils, highlighters, etc.).
6. Based on the criteria chosen above (in step 2), the class chooses which color is the winner.
    a. Each group's color will then be revealed.
7. A whole class discussion will facilitate a comparison of the graphs between groups and given activity graphs.
    a. Discuss what they could have done differently to create graphs closer to the graphs given to them.
    b. Discuss why their graphs are not identical to the graphs given to them.

Differentiation:

- ELL: Put them in groups with stronger students who will assist them in understanding.
- TAG: Have them create their own scenario and their own graph for the Describing Motion and Position Using Graphs Worksheet.
- Special Education: Provide the labels on graphs axes for the Describing Motion and Position Using Graphs Worksheet.

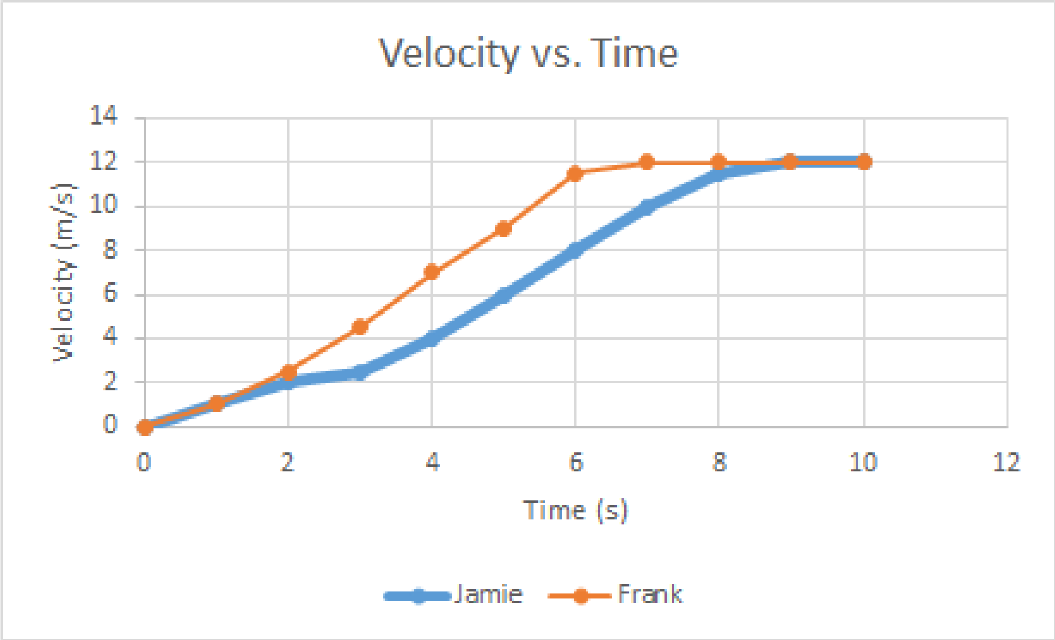
Assessment:

Use the *Describing Motion and Position Using Graphs* assessment worksheet to check for understanding at the end of the progression:

- Graph axes may be filled in for students with special needs.
- ELL students may be allowed to use verbal descriptions to answer the questions.

Describing Motion and Position Worksheet

Name: ______________________ Date: _____________



1. How does velocity relate to acceleration? From 2-4 seconds, did Jamie or Frank accelerate faster? Explain why.

____

____

____

2. What does a horizontal line on each graph indicate about the motion?

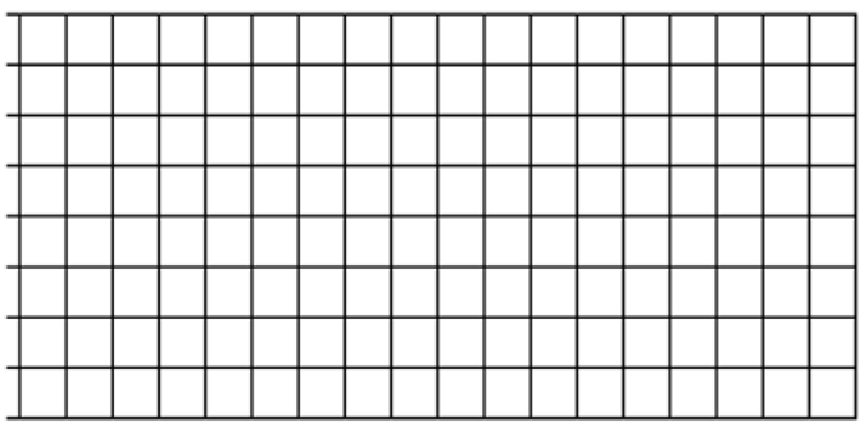
   Position vs. time ______________________________

   Velocity vs. time ______________________________

   Acceleration vs. time ______________________________

   Direction vs. time ______________________________

3. John starts timing and documenting the speed of the car while his mother is driving. She is going 25 km/h for the first 10 seconds and then speeds up to 35 km/h in 5 seconds. She stays at 35 km/h for 5 seconds until she comes to a red light and stops in 10 seconds. Draw and label the velocity vs. time graph.



Describing Motion and Position Assessment Key and Rubrics

Question 1 Rubric:

Item/Score	0	1	2	3
Mathematical Concepts	Velocity and acceleration are not related.	An incorrect relationship between velocity and acceleration is presented.	A relationship between velocity and acceleration is correct but does not demonstrate understanding (e.g. m/s/s).	Acceleration is defined as the change in velocity over change in time.
Explanation	Fails to state that Frank accelerated at a faster rate.	Claims that Frank accelerated at a faster rate without an explanation.	Claims that Frank accelerated at a faster rate with a partial explanation (e.g. steeper graph).	Claims that Frank accelerated at a faster rate with with an explicit explanation (e.g. steeper graph means that velocity changes at a faster rate which means a higher value of acceleration).

Question 2 Answer Key:

Position vs. time _Object is not moving___________

Velocity vs. time _Object is moving at constant velocity_ _

Acceleration vs. time _Object is accelerating at a constant rate_

Direction vs. time _Object is moving in a straight line_____

Question 3 Rubric:

Item/Score	0	1	2	3
Accuracy of Plot	Points are not plotted correctly or extra points were included.	Most points are plotted correctly or some points are missing.	All points are plotted correctly and are easy to see but may not have carefully drawn lines.	All points are plotted correctly and are easy to see. A ruler is used to neatly connect the points or make the bars, if not using a computerized graphing program.
Title	A title is not present.	A title is present at the top of the graph but does not relate to the graph.	Title relates to the graph but may not be completely correct.	Title is explicit and printed at the top of the graph.

Labeling of X-Axis	The X axis is not labeled.	The X axis has a label without units.	The X axis is labeled with the units only (e.g. seconds, minutes)	The X axis has a clear, neat label that includes the units used for the independent variable (e.g, time).
Labeling of Y-Axis	The Y axis is not labeled.	The Y axis has a label without units.	The Y axis is labeled with units only (e.g, m/s, meters).	The Y axis has a clear, neat label that includes the units for the dependent variable (e.g, velocity, acceleration, distance, direction).

Unit 2

A World with Friction

Goals:

To educate middle school students about friction and how it affects driving. Students will understand that there are forces and factors that influence motion, including mass, velocity, and friction.

Justification:

Middle school students have many misconceptions about physics, particularly friction. These misconceptions are as follows:

- Friction is caused by surface roughness (there are many times when this is indeed true, but others where a surface may not be as rough but still have more friction, ex: the sticky side of tape is less rough than sandpaper but has more friction)
- An object doesn't stop because of a presence of a force; it stops because of an absence of a force
- Objects at rest have no forces acting on them
- Moving objects come to a stop even when there is no friction
- Friction only occurs between solids
- There are tiny bumps that cause friction (the use of sandpaper)
- Friction always hinders motion; reducing friction is always desired

The science teacher should identify where these misconceptions come from, and provide experiences for students to address these ideas to construct scientifically accepted understandings.

Lesson One: Factors that Affect Motion

Grade level: 6-8

Expected length of lesson: 45-90 Minutes

Overview:

This lesson will serve as an in introduction to the driving simulator activity. Students will collect data and draw conclusions about how different variables such as mass, velocity, and friction affect motion. Students will then be introduced to the stopping distance calculation that they will use in the driving simulation activity.

Standards and Benchmarks:

NGSS:

Performance Expectations:

- MS-PS3-5:
  - Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

Disciplinary Core Ideas:

- MS-PS3-1:
  - Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.

- MS-PS3-5:
    - When the motion energy of an object changes, there is inevitably some other change in energy at the same time.

Cross-Cutting Concepts:

- MS-PS2-1, MS-PS2-1:
    - Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

Science and Engineering Practices:

- MS-PS2-4:
    - Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
- MS-PS2-5:
    - Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.

Iowa Core

Science:

- S.6-8.PS.3:
    - Understand and apply knowledge of motions and forces.

Mathematics:

- 6.EE.C.9:
  - Use variables to represent two quantities in a real–world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation.
- 6.EE.B.6:
  - Use variables to represent numbers and write expressions when solving a real–world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.

Literacy:

- WHST.6-8.1:
  - Write arguments focused on discipline–specific content.
- WHST.6-8.10:
  - Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline–specific tasks, purposes, and audiences.

Learning Goals:

Students will understand that:

- There are many forces and factors that influence motion, including mass, velocity, and friction.
- Friction is a force that opposes motion.
- Velocity is a measure of distance traveled during a certain time.
- Mass is what is pulled on by gravity to determine weight.
- Stopping distance varies with road surface conditions (friction), mass of the vehicle, and velocity of the vehicle.

Learning Performances:

Students will be able to:

$$d = \frac{v_0^2}{2\mu g}$$

- Solve the stopping distance equation:

- Describe the effects that velocity, friction, and mass have on the motion of an object.

Materials:

- Friction Probe #17 *Uncovering Student Ideas in Physical Science* 2010 (by Page Keeley)
- 3 small model cars
- 3 ramps
- Weight to attach to car (to increase mass of car)
- Towel or other material (to increase friction)
- Textbooks to elevate ramps (for control experiment and to increase velocity)

Students' Ideas:

- Students may think there is no friction between stationary objects.
- Students may not know terms such as mass, velocity, and friction.
- Students may not realize what factors affect stopping distance.

Critical Thinking Questions:

- What factors affect motion?
- What factors affect stopping distance of a vehicle?

Main Lesson:

The teacher gives a brief outline of the simulation project and shows a video of the simulator being driven so students know what to expect. This engages students and prepares them for driving the simulator, as they do not have driving experience.

1. The teacher administers the Friction Probe to elicit students' current understanding/misconceptions about friction and forces. The teacher passes out the friction probe, or projects it and students will have 5 minutes to complete it or write their answers in their science notebooks. The teacher collects the probe to see what misconceptions students have about friction and tallies the responses on the board.
2. Students are broken into groups of 3 (Simulation Groups). Within each group, students decide which area of expertise to join, either mass, friction, or velocity (Expert Groups). If there need to be 4 students in a Simulation Group, two students should join Expert Group 2: Friction.

Expert Groups:
a. Group 1: Mass
b. Group 2: Friction
c. Group 3: Velocity

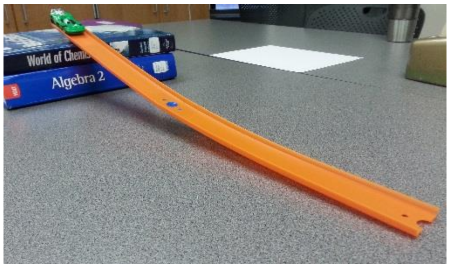
The goal is for each student to become an expert in one area, which they will later bring back to their group to assist in the simulation. The three groups do three variations of the activity to see how different factors affect stopping distance. Each student receives a worksheet on which to record their predictions, data, and conclusions.

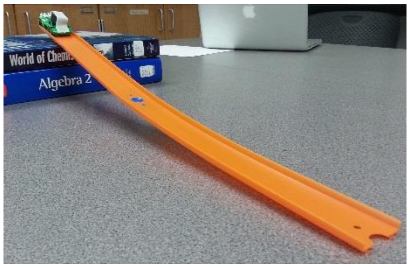
3. Each Expert Group sets up a ramp and rolls a toy car down it to measure how far from the bottom of the ramp it stops. They record this on their worksheet. Then they perform the activity according to their specific variation.

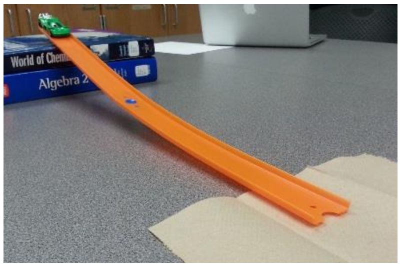
   a. Expert Group 1 weighs their car, then adds a weight to it and weighs it again. They measure the stopping distance of the car with the added mass.

   b. Expert Group 2 adds a paper towel to the bottom of the ramp (at least as long as the meter stick) to increase friction and records the stopping distance of the car on the new surface.

   c. Expert Group 3 makes their ramp steeper (2 times steeper if possible) so the velocity of the car is increased. They measure their new stopping distance.








4. Students draw conclusions in their Expert Groups, then have a whole class discussion where one or two students from each Expert Group share their findings with the rest of the class by drawing a picture on the board and orally describing their observations. All students should record the conclusions of each group.

5. The teacher passes back the Friction Probe papers and then reviews the correct answers with the students. Students make changes to their original ideas on their papers or in their science notebooks.
6. Students get into their Simulation Groups and the teacher introduces the stopping distance equation used for the simulation activity. Students should understand what each variable means, and they should be exposed to some examples of how to use the equation.

$$d = \frac{v_0^2}{2\mu g}$$

d = stopping distance
v = velocity
μ = coefficient of friction
g = gravity

7. Wrap up:
    a. The teacher gives brief instructions for how the simulation day will proceed so that students are organized and prepared.

Differentiation:

Special Needs Students:

- Assistive technologies such as Dragon, Read & Write GOLD, etc.
- Modeling of tasks
- Modified worksheets or notes provided by the teacher

ELL Students:

- Strategic grouping
- Modeling of tasks
- Pictures
- Vocabulary list of difficult terms: mass, velocity, friction, stopping distance, force, motion, ramp, vehicle, variable, control group, experimental group
- Word-bank for worksheet
- Allow use of translation devices

Advanced Learners:

- Can be introduced to more advanced formulas and concepts, such as how friction is determined ($F=\mu N$, Frictional Force=coefficient of friction times Normal Force) and how speed could be adjusted to produce different stopping distances.

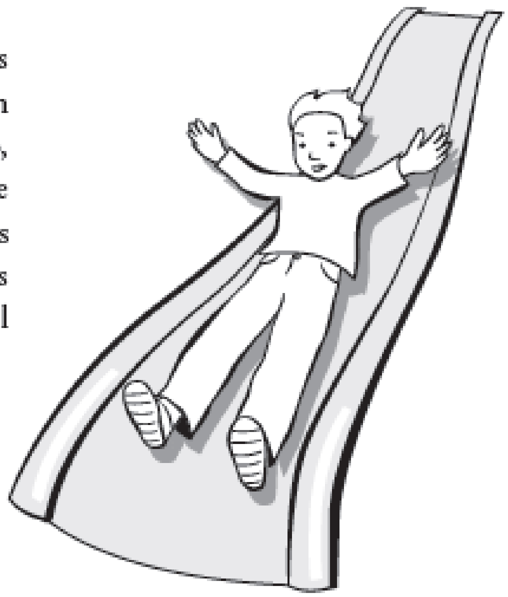
Assessment:

- Formative assessment:

  - Friction Probe (pre-lesson and post-lesson)
  - Student presentations of findings from Expert Groups
  - Simulation calculations and performance
- Summative assessment:
  - Activity Worksheet
  - Activity Homework
  - Assessment quiz
  - Class discussion

Friction

Ansel slides down the playground slide. He notices that the new pants he is wearing slow him down on the slide. When he mentions this to his friend Sergio, Sergio says the rubbing of Ansel's pants against the slide was caused by something called friction—and it is the friction that made Ansel slow down. Ansel wonders about the other ways friction could occur. Check off all the kinds of contact that could cause friction.



_____ **A** Car tires rolling on the road

_____ **B** A magnet on the front of a refrigerator

_____ **C** A box sliding down a hill

_____ **D** A box sitting on the slope of a hill (not moving)

_____ **E** A box sitting on a flat table

_____ **F** Rollerblading on a flat road

_____ **G** Ice skater gliding on an ice rink

_____ **H** Car parked on a steep driveway (not moving)

Friction

Teacher Notes

Purpose

The purpose of this assessment probe is to elicit students' ideas about friction between solid objects. The probe is designed to determine (a) whether students recognize friction as an interaction between two objects or materials that rub against/slide over each other and (b) whether they limit this interaction to a particular type of matter or contact.

Related Concepts

contact force, friction, interaction, kinetic friction, rolling friction, sliding friction, static friction

Explanation

All of the choices are examples of friction with the exception of E (box sitting on a flat table). A wheel rolling on a surface is an example of "rolling friction." A magnet is attracted to the refrigerator with a magnetic force, but it is the frictional force that prevents the magnet from sliding down the front of the refrigerator. A box would slide down a hill if there were no friction between the box and the hill. Although an ice rink provides a low friction surface, there is still some friction between an ice skate and the ice rink (the skater will eventually slow down and stop if she does not push off). Even a clothespin can only work because of the friction force between the clothes and the surface of the clothespin. In all of the examples except for A and F, which are examples of rolling friction, the friction force acts parallel to the two surfaces that are in contact with each other. Because the surfaces are sliding past each other, C and G are examples of what is called "kinetic friction." The other examples (except for A and F) are called "static friction" because the surfaces are not moving relative to one another.

Administering the Probe

This probe is best used with middle school and high school students. It can also be used with upper elementary students by removing the static friction distracters that don't involve a visible rubbing or sliding (i.e., B, D, H, and I).

Related Ideas in *National Science Education Standards* (NRC 1996)

5–8 Motions and Forces

★ Unbalanced forces will cause changes in the speed or direction of an object's motion.

9–12 Motions and Forces

- Objects change their motion only when a net force is applied.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 1993, 2009)

3–5 Motion

- Changes in speed or direction of motion are caused by forces.

6–8 Motion

★ An unbalanced force acting on an object changes its speed or direction of motion,

- In a group of 47 secondary students, the following ideas about friction were held: Friction occurs only between solids (12 students) and friction occurs with liquids but not with gases (10 students). Only 16 students called friction a force (the responses of 9 students were in an "other" category) (Stead and Osborne 1980).

Suggestions for Instruction and Assessment

- Ask students to recall times when they easily slid down a slide on a playground and other times when they were slowed down on the slide. Ask them to compare the interaction between themselves and the slide that occurred in each case.
- It is important to develop the concept of interactions when teaching about friction.
- Encourage students to come up with examples of friction involving moving and stationary objects.
- Consider extending the probe to examples that include fluid friction, such as the drag on an object in air or water.
- Research shows that some students may

experimental interventions in solid friction and fluid statics. *International Journal of Science Education* 26 (9): 1083–1110.

Clement, J. 1993. Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. *Journal of Research in Science Teaching* 30 (10): 1241–1257.

Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. *Making sense of secondary science: Research into children's ideas.* London: RoutledgeFalmer.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academies Press.

Stead, K., and R. Osborne. 1980. Friction. LISP working paper 19. Hamilton, New Zealand: University of Waikato, Science Education Research Unit.

Stead, K., and R. Osborne. 1981. What is friction? Some children's ideas. *New Zealand Science Teacher* 27: 51–57.

2. In your Simulation Group, explain to the other members what data you found in your Expert Group.

Friction Matters Homework

Name: ______________________ Date: ____________

Definitions: Write your own definitions to each vocabulary word listed below.

Friction: ____
____

Mass: ____
____

Velocity: ____
____

Force: ____
____

Stopping Distance: ____
____

Equations: Based off of the given equation, match the variables with their abbreviations.

$$d = \frac{v_0^2}{2\mu g}$$

d = _______________

v = _______________

μ= _______________

g = _______________

Discussion Questions: Use the space provided to answer the questions in complete sentences.

1. Explain how surface type influences the amount of friction.

____

____

____

2. Analyze how friction can be both a positive and negative part of our everyday lives. Use examples to support your statements.

POSITIVE: ____

____

____

NEGATIVE: ____

____

____

3. Describe what a daily activity would be like if there were no friction. How would the activity be easier, and how would it be more difficult?

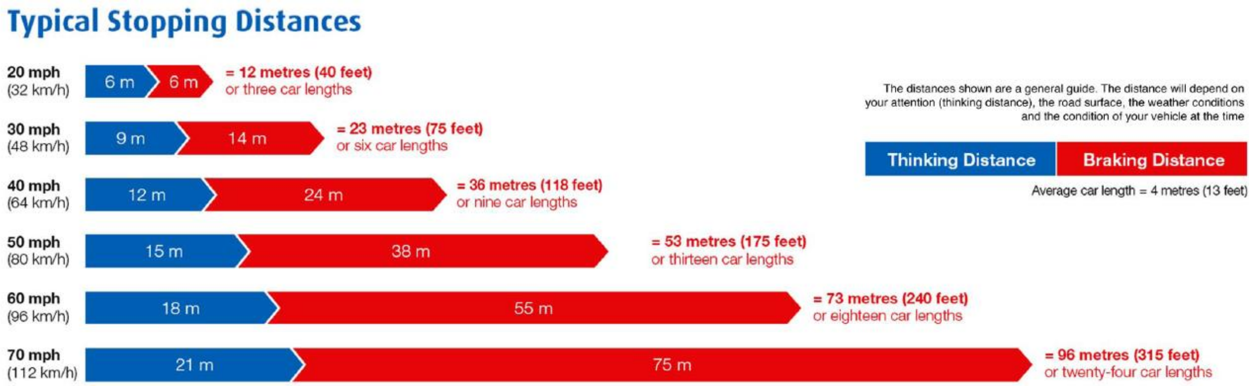
____

____

____

____

Further Your Thinking: Consider the picture below when answering the question below.



1. How might reaction time influence your stopping distance?

____
____
____
____
____
____
____

Fiction Matters Homework Teacher Key

Definitions: Write your own definitions to each vocabulary word listed below

Friction: ________The resistance of motion when one object rubs against another____
____

Mass: ________A measure of a numbers of atoms in an object______________________
____

Velocity: ________The speed and direction of an object_________________________
____

Force: Strength or energy that causes a physical action or motion

Stopping Distance: Measured amount of space it requires to become stationary

Equations: Based off of the given equation, match the variables with their abbreviations.

$$d = \frac{v_0^2}{2\mu g}$$

d = stopping distance

v = velocity

μ= coefficient of friction

g = gravity

Discussion Questions: Use the space provided to answer the questions in complete sentences.

1. Explain how surface type influences the amount of friction.

   Answers may vary. Generally, a rougher surface causes there to be more friction and a smoother surfaces causes less friction.

2. Analyze how friction can be both a positive and negative part of our everyday lives. Use examples to support your statements.

   POSITIVE: Answers may vary. Friction allows you to travel, play sports, write with your pencil and many more things. Without friction we would always be moving unless stopped by an outside force.

NEGATIVE: Answers may vary. Friction causes you to lose energy while traveling, playing sports and writing with your pencil. Without a stronger opposing force friction would always slow you down.

3. Hypothesize what a daily activity would be like if there were no friction. How would the activity be easier, and how would it be more difficult?

Answers may vary. When going to school without friction you would have to accurately aim and push off from your front door. You'd have to hope to not hit any objects that may change your route. This would make getting to school faster as long as you didn't run into any objects but would make it much more difficult overall and probably painful.

Further Your Thinking: Consider the picture below when answering the question below.

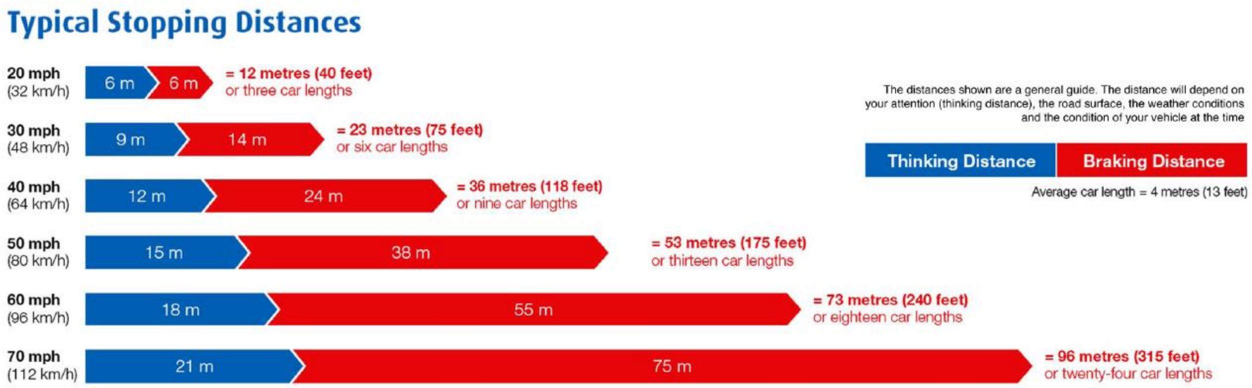


Photo from The Department of Transportation Highway Code

1. How does reaction time and distance change when your vehicle goes faster?

Answers may vary. As your car goes faster, you travel further during your reaction time, causing your stopping distance to be longer.

Lesson Two: Simulation Driving Day

Grade level: 6-8

Expected length of lesson: 45 minutes

Overview:

The purpose of the lesson is to have students collect data on stopping distance using a combination of variables. Students are assigned their variable combination and are to complete their calculations predicting the stopping distance needed with that variable combination. The variables are: car type (either the BMW or Expedition) and coefficient of friction (COF) (0.85, 0.4, or 0.2). There are six possible car and coefficient of friction combinations: BMW+0.85 Coefficient Of Friction, BMW+0.4 COF, BMW+0.2 COF, Expedition+0.85 COF, Expedition+0.4 COF, and Expedition+0.2 COF. Students drive the simulator for their given variables. The simulation will be set up to match each group's variable combination when they arrive at the simulator. After students run the simulation for their assigned variables they record their results, discuss their results with class members, and partake in journaling as an assessment.

Standards and Benchmarks:

NGSS:

Performance Expectations:

- MS-PS2-2:
  - The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- MS-PS2-1:
  - For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).

Cross-Cutting Concepts:

- MS-PS2-3, MS-PS2-5:

  - Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- MS-PS2-1, MS-PS2-4:
  - Models can be used to represent systems and their interactions such as inputs processes and outputs and energy and matter flows within systems.
- MS-PS2-2:
  - Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

Science and Engineering Practices:

- MS-PS2-4:
  - Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
- MS-PS2-2, MS-PS2-4:
  - Science knowledge is based upon logical and conceptual connections between evidence and explanations.

Iowa Core

Science:

- S.6–8.PS.3:
  - Essential Concept and/or Skill: Understand and apply knowledge of motions and forces. The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

Comprehension and Collaboration:

- SL.8.1:
  - Engage effectively in a range of collaborative discussions (one–on–one, in groups, and teacher–led) with diverse partners on *grade 8 topics, texts, and issues*, building on others' ideas and expressing their own clearly.
- SL.8.2:
  - Analyze the purpose of information presented in diverse media and formats (e.g., visually, quantitatively, orally) and evaluate the motives (e.g., social, commercial, political) behind its presentation.
- SL.8.3:

- Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identifying when irrelevant evidence is introduced.

Presentation of Knowledge and Ideas:

- SL.8.4:
  - Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well–chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Learning Goals:

Students will understand:

- Motion is dependent on the forces acting on it. In our simulation, the motion of the car is dependent on the amount of friction of the pavement.
- The relationship between friction and stopping distance.
- How a simulation can be used to demonstrate a topic in a novel and real-world way.

Learning Performances:

Students will be able to:

- Properly calculate stopping distance given the variables: car type and coefficient of friction.
- Understand how friction and stopping distance are related by understanding that an increase in friction means a decrease in stopping distance (higher friction (closer to 1.0) means less time required to stop).

Materials:

- Calculations from the previous day
- Their science journals or notebooks to write down observations and discoveries
- The MiniSim Simulator provided by the National Advanced Driving Simulator

Safety:

- Safety guidelines for simulation use from NADS:

- Do not use if you have motion sickness
- Do not use if you have any medical condition that would make your participation unsafe for you (heart condition, etc.)

Students' Ideas:

There are two different aspects that students should know before the day of the simulation. The first idea is the definition of friction and how friction impacts everyday life. If students do not know what friction is they will not understand why there is a difference between pavement conditions. The second idea that students should know is how to do the mathematical calculation needed to figure out stopping distance. If students do not know how to use this calculation they will be unable to predict stopping distance for their given variables. Students will come into this topic with some misconceptions that need to be addressed and will hopefully be corrected during this lesson. The misconceptions that students may have are:

- Friction is caused by surface roughness (there are many times when this is indeed true, but others where a surface may not be as rough but still have more friction, ex: the sticky side of tape is less rough than sandpaper but has more friction)
- An object doesn't stop because of a presence of a force; it stops because of an absence of a force
- Objects at rest have no forces acting on them
- Moving objects come to a stop even when there is no friction
- Friction only occurs between solids
- There are tiny bumps that cause friction (the use of sandpaper)
- Friction always hinders motion; reducing friction is always desired

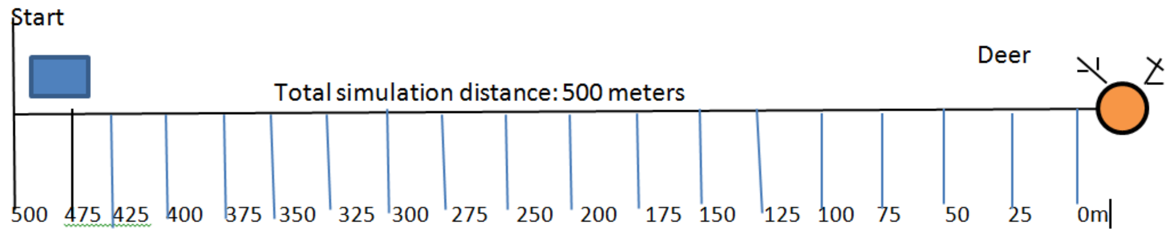
Critical Thinking Questions:

- How much stopping distance does each vehicle require to stop safely at different driving conditions?
- Which vehicle will stop in a shorter distance? Why do you think that?
- What other factors might affect stopping distance?
- Why might your calculations have been off?
- How is the simulator different than the real world?

Main Lesson:

Introduction:

Because these students are at a particular age when driving begins to be relevant to their lives, the simulation assists in their understanding of the concept of friction in a way that relates to their futures in driving. By using this real world scenario as a teaching tool, the students are more likely to engage in the classroom and be prone to learning. Before completing the simulation, students are to make predictions of how much stopping distance is required. After the simulation, those predictions are to be proven true or false, therefore, correcting any misconceptions or reinforcing the concept. Below is a rough drawing of what the simulation will look like:



Lesson:

1. The teacher splits the class into their Simulation Groups (about 3 students) and each team is assigned a combination of variables (BMW+0.85 COF, BMW+0.4 COF, BMW+0.2 COF, Expedition+0.85, Expedition+0.4, or Expedition+0.2).
2. Students will then plug in their variables to the stopping distance equation found below.

$$d = \frac{v_0^2}{2\mu g}$$

v=velocity=50mph=22.352meters/second

g=gravity=9.8meters/second^2

μ=coefficient of friction

d=stopping distance

3. After the groups have computed their stopping distance they have to take turns driving the simulator. When one group is driving the rest should be journaling about what they predict will happen and how much stopping distance they will require to stop safely. The students can also practice the simulation by walking through what might happen and applying the mathematical equation above. Students within the groups driving the simulator assist the driver by recording the road maker at which they applied the brakes, the marker at which the vehicle came to a complete stop, and whether or not the vehicle hit the deer or stopped safely before it.

4. After driving the simulator the groups write another journal entry about the experience, whether their calculation was accurate, and whether they successfully completed the simulation.

5. When all groups have finished the simulation and journaling any remaining class time is to be used to discuss the results. The following class time will focus on these results and use official graphs from the simulation to interpret which team did a better job at stopping under each condition.

6. After completing the simulation students journal about their findings and defend or reevaluate their predictions from day one. If remaining class time allows, the entire class can discuss what each group's results were and whether or not they correlate with the mathematical calculations.

Differentiation:

Students with Special Needs:

- For those students who are unable to be in the simulator because they get motion sickness, are unable to drive due to physical or mental disabilities, or have a health condition that prevents them from driving arrangements can be made to watch other students drive or to watch a video of someone driving in order to still see the results.
- Students who are unable to physically drive the simulator could serve the role as a stopping distance recorder or team coach to satisfy their participation during the simulation.

ESL Students:

- For those who are ESL students, additional pictures, a vocab list, definitions, or modeling may be beneficial. Such vocab list could include the following terms: mass, velocity, stopping distance, and meters.
- A modified thinking guide may also be used for students whose first language is not English. More definitions or instructions may be used to aid the student, or a guide could be created incorporating their native language.

Advanced Learners:

- For advanced learners, a modified thinking guide with less structure or information may be possible.
- Another opportunity for advanced learners would be the equation below. This equation is too advanced for most middle school students. This equation is used to calculate how much time it takes to accelerate to 0mph from 50mph as opposed to the stopping distance calculation used with non-advanced learners.

$$a = \frac{v_f - v_o}{t}$$

a = average acceleration

v_f = final velocity

v_0 = initial velocity

t = time

Assessment:

- By use of journaling and verbal explanation to the opposing teams the teacher can see how well each student understands why their results were the way they were and how the experiment is validated by this information.
- Students will construct an explanation as to how friction played a role in the results they got from the simulation. They will also explain why their calculations were similar or different from the results they obtained in the simulation. Finally,

students will explain how differing masses and coefficients of friction would change how much stopping distance is required.

- After each group records their results from the simulation students will give a verbal explanation defending or refuting the results that they received.

Driving With Friction Worksheet

Name: ______________________ Date: _____________

Materials: Use the following materials to complete the activity stated below.

- MiniSim Simulator
- Science Journals or Notebooks
- Calculations from the previous day

Activity Step by Step: Use the following steps to complete the activity and in complete sentences answer the questions below.

1. In your groups of three you will be assigned a combination of variables.
    - YOUR ASSIGNED VARIABLES ARE: __________________________
2. Plug in your variables into the stopping distance equation.

$$d = \frac{v_0^2}{2\mu g}$$

d = stopping distance

v = velocity = 50 mph = 22.352 meters/second

μ = coefficient of friction

g = gravity = 9.8 meters/second^2

YOUR REQUIRED STOPPING DISTANCE: ____________________

3. When driving the simulator one student within your groups will be the driver, one will be the recorder, and the other will be the driving assistant.
    - YOUR ASSIGNED JOB IS: ___________________________________
        - Driver: drive the simulation according to your calculations
        - Driving Assistant: help the driver by accurately counting the meter markers and preparing them to stop safely
        - Recorder: record your data found during the simulation.

4. If another group is using the simulator use this time to journal about your predictions. You can also practice the simulation by walking through what might happen and applying the equation.

5. After computing your stopping distance required to safely stop while driving the MiniSim, complete the simulation within your group.

6. After completing the number of trials of the simulation assigned to your group, record your data and your conclusion in your lab journals and answer the questions found below in complete sentences.

7. When all groups have finished the simulation and journal entries, discuss with the class your individual findings and interpretations of the data.

Predictions: Use the space below to answer the questions in complete sentences.

1. Based off of what you know about friction from previous activities completed in class, predict what you think will happen when your assigned variables are applied to the simulation.

____

____

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____

Experiment Data: Add your data found in the experiment to the chart below.

	Road Marker When Brakes Were Applied	Road Marker When Car Came to Complete Stop
Driving Run 1		
Driving Run 2		
Driving Run 3		
Average		

Conclusion: Use the space below to answer the questions in complete sentences after discussing with the rest of the class about their data.

1. Based on the data that you have collected about your assigned variables, what can you conclude about how different masses affect your ability to stop versus the different surface frictions?

   ____

   ____

   ____

2. Did you complete the simulation successfully? If not, what could you have done differently to complete it?

   ____

   ____

   ____

   ____

Lesson Three: Finalizing Friction

Grade level: 6-8

Expected length of Lesson: 45 minutes

Overview:

Students will be given the Finalizing Friction Quiz to assess their understanding of the concepts that are used in the previous lessons. After the quiz students engage in either an open or guided discussion of the simulation activity and/or discuss the concepts themselves, clearing up any misconceptions that still persist. There may also be opportunity for further journaling.

Standards and Benchmarks:

NGSS:

Performance Expectations:

- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. (MS-PS2-2)
- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law). (MS-PS2-1)

Cross-Cutting Concepts:

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3),(MS-PS2-5)
- Models can be used to represent systems and their interactions such as inputs processes and outputs and energy and matter flows within systems. (MS-PS2-1),(MS-PS2-4)
- Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales. (MS-PS2-2)

Science and Engineering Practices:

- Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-PS2-4)
- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS2-2),(MS-PS2-4)

Iowa Core:

Science:

- S.6–8.PS.3: Essential Concept and/or Skill: *Understand and apply knowledge of motions and forces.*The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

Comprehension and Collaboration:

- SL.8.1: Engage effectively in a range of collaborative discussions (one–on–one, in groups, and teacher–led) with diverse partners on *grade 8 topics, texts, and issues*, building on others' ideas and expressing their own clearly.
- SL.8.2: Analyze the purpose of information presented in diverse media and formats (e.g., visually, quantitatively, orally) and evaluate the motives (e.g., social, commercial, political) behind its presentation.
- SL.8.3: Delineate a speaker's argument and specific claims, evaluating the soundness of the reasoning and relevance and sufficiency of the evidence and identifying when irrelevant evidence is introduced.

Presentation of Knowledge and Ideas:

- SL.8.4: Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well–chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Learning Goals:

- Students will have an understanding of motion in how it relates to friction and mass.
- Students will engage in discussion using their newfound understandings of motion and friction expanding and challenging those ideas when prompted.

Learning Performances:

- Students will be given a quiz, discussion prompts, and journaling prompts to show their understanding of the material.

Materials:

- Finalizing Friction Quiz
- Discussion prompts (Main Lesson)
- Journaling prompts (Main Lesson)

Students' Ideas:

By engaging in the Friction and Simulation lessons students have a more complete understanding of how friction and mass affect the motions, and ultimately stopping distance, of a vehicle. Students use what they know about friction and apply it to other real world examples. There may be some misconceptions of what friction is because it can be more abstract than tires on pavement. The purpose of this lesson is to draw out what misconceptions may be lingering and to correct them.

Critical Thinking Questions:

- What could you do next time to improve your results?
- How has your understanding of friction changed after the simulation?
- What are some other real world examples that apply the ideas of friction and motion?

Main Lesson:

1. The quiz can be given at the beginning or the end of the lesson, be sure to allow a minimum of 10 minutes for the students to finish the quiz. The quiz is provided with this document.
2. The journaling portion of this lesson is optional, but encouraged. There should be at least three distinct prompts written on the board for the students to choose from. Encourage them to write as much as possible about one before writing about another. The students should be given 15 minutes to write. If they do not have a separate journal for the entire class this could be turned in for a completion grade, or used just as a prompt for the discussion. Here are some suggested journal prompts, but feel free to come up with unique ones to suit the classroom.
    a. Journal Prompts:
        1. What would the world be like if there was no friction?
        2. What are some reasons people try to increase (or decrease) friction as much as possible?
        3. What are some unique ways that car makers could make stopping distance even shorter?
        4. How would you teach a class about friction?
3. There are two ways to do the discussion portion of this lesson, teacher led or student led. It is encouraged to have this discussion at the end so any extra time from the other activities can be utilized here.
    a. Discussion Prompts/Suggestions
        1. The teacher led discussion has the teacher asking specific question and asking students to engage with their own unique experiences or insight. The overall goal is to get the students to challenge their understanding of friction and motion. They realize that even though it is the end of the lesson that these concepts are much larger than they think. This hopefully sparks intrigue into the subject matter and promotes further independent learning. Here are some suggested discussion prompts.
            a. If there is any disagreement over the quiz questions now is a good time to go over any of those.

   b. The journal prompts can serve as good discussion topics since the students have already formed thoughts about those topics.
   c. Ask for any comments or opinions about the unit.
   d. Find a short video that uses friction in interesting or counterintuitive ways. Then have the students talk out what they think is happening.
2. The student led discussion is only encouraged for classrooms that are very task oriented and maybe towards the higher end of the suggested age range. The goal of this discussion method for the teacher is to create civil disagreement among the students. In this debate style atmosphere students are forced to refine and articulate their beliefs to their peers. Many times this leads to realizations about the topic and further help solidify their understanding of the topic. Here are some ideas that will help to promote this type of discussion, remember to allow the last 5 minutes to clear up any misconceptions that presented during the discussion.
   a. If there are any major disagreements over the quiz questions a good way to start off is to have the students take a side and discuss/defend their way of thinking.
   b. Other more thought provoking questions can also be instituted here. Such as, "Is a magnet holding a piece of paper on a refrigerator utilizing friction?" The best way to go about this method of discussion is to prompt the class, see where there is any disagreement, and then let the two sides discuss. Playing the devil's advocate may be necessary for this.

Differentiation:

<u>Special Needs Students:</u>

- Students may need extended time for the quiz or take the quiz orally with the teacher or an aid. If they are uncomfortable speaking in a group setting, they could extend the journaling or have a more private discussion session.

<u>ELS Students:</u>

- English language learners could benefit from a word bank or more illustrations to help them understand the tasks. If there is another student in the class that is fluent in both languages, have them work together.

<u>Advanced Learners:</u>

- Advanced learners could benefit from incorporating more calculations (options will be provided on the quiz) or more advanced concepts, such as energy conservation. The student led discussion is also a good option for more advanced students to engage and challenge one another.

Assessment:

This entire day will serve as an assessment for the previous lessons. The quiz will provide quantitative assessment while the journaling and discussion will help to show comprehensive understand of friction and motion concepts.

Finalizing Friction Quiz

Name: ______________________ Date: _____________

Short Answer Instructions: Answer the following questions in complete sentences.

1. What conditions had the shortest stopping distance? Why?

2. What are some factors that could have caused errors in your data during the simulation?

Multiple Choice Instructions: Circle the correct answer and use the space provided to explain your answer.

3. Which of the following is an example of increasing friction? Briefly explain your answer.
   a. Squirting oil into door hinges
   b. Spreading sand on icy roads
   c. Waxing a snowboard

4. Which of the following is <u>NOT</u> an example of friction? Briefly explain your answer.

a. A baseball traveling through the air

b. A box sitting on a flat table

c. A boat floating across a lake

____

____

____

Further Your Thinking: Use the equation below to answer the questions.

$$F = m \times a$$

5. A car starts out traveling at 22.4 m/s (about 50 mph) and has a mass of 2722 kilograms. The driver sees a deer in the distance and slams on the brakes causing a force of 1500 newtons. Using the equation provided, what is the acceleration of the vehicle?

____

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6. What does this acceleration mean?

____

____

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____

Finalizing Friction Quiz Teacher Key

Short Answer Instructions: Answer the following questions in complete sentences.

1. What conditions had the shortest stopping distance? Why?

   The BMW with completely dry pavement theoretically has the shortest stopping distance.

2. What are some factors that could have caused errors in your data during the simulation?

   Reaction time, how hard the brake is being pressed, not traveling in a straight line should be the most common answers.

Multiple Choice Instructions: Circle the correct answer and use the space provided to explain your answer.

3. Which of the following is an example of increasing friction? Briefly explain your answer.

   a. Squirting oil into door hinges

   b. Spreading sand on icy roads

   c. Waxing a snowboard

   Answers B should be circled. Explanations may vary. B: Spreading sand on icy roads. The sand will increase surface friction by creating a courser surface.

4. Which of the following is NOT an example of friction? Briefly explain your answer.

   a. A baseball traveling through the air

   b. A box sitting on a flat table

   c. A boat floating across a lake

   Answer B should be circled. Explanations may vary. B: The only force acting on the box is gravity and friction requires two objects to be sliding past one another or trying to.

Further Your Thinking: Use the equation below to answer the questions.

$$F = m \times a$$

5. A car starts out traveling at 22.4 m/s (about 50 mph) and has a mass of 2722 kilograms. The driver sees a deer in the distance and slams on the brakes causing a force of 1500 newtons. Using the equation provided, what is the acceleration of the vehicle?

   Answer: 0.55 m/s2

6. What does this acceleration mean?

This means that every second the vehicle will be slowing down by 0.55 meters per second, until the vehicle comes to a complete stop.

Appendix

List of Contributors:

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The University of Iowa

Jacob Byers

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Appendix B Curriculum Materials for Driver Distraction

Unit 3: Distracted Driving

Contributors: Spencer Gibson, Hannah Luber, Jacob Swift, Leslie Flynn Ph.D., Matthew Cain M.A.T.

The University of Iowa

Introduction

The following lesson plan concerning distracted driving is the third unit of a three unit curriculum developed in cooperation with the National Advanced Driving Simulator (NADS). The content of the curriculum is aligned with the Next Generation Science Standards at the middle school level. All units in the curriculum integrate miniSim technology supplied by NADS. The following unit (Unit 3: Distracted Driving) is composed of three individual lessons in which students learn physics concepts and develop data analysis skills while being exposed to the dangers of distracted driving.

Partners

University of Iowa College of Education

Leslie Flynn, PhD: Lead partner- Curriculum design, Innovator of STEM initiatives

Matthew Cain, M.A.T: Field Consultant, High school physical science teacher and STEM instructor (West Branch)

Jacob Swift: M.A.T candidate (physics), Partner communication, Curriculum design

Hannah Luber: B.S Science Education (physics), Data analysis, Curriculum design

Spencer Gibson: M.A.T student (physics), Survey, Curriculum design

National Advanced Driving Simulator

Dr. Chris Schwarz: Research scientist, Project consultant on Explore the Science of Driving Project for SAFER-Sim.

Dr. Tim Brown: Research scientist, Co-Principle investigator for Explore the Science of Driving project for SAFER-Sim.

Dawn Marshall: Director of the SAFER-Sim University Transportation Center grant, Research Manager at NADS, Provides overall direction to the project from the center's perspective.

Alec LaVelle: Research assistant, Simulation creator (coder), Outreach support (miniSim)

Jacob Heiden: Research assistant, Outreach support (miniSim), Administrative Support

Overview

Unit 3: Distracted Driving

Lesson 1: Distracted Viewing

- Students are split into two groups and watch a short video, then attempt to answer follow up questions.
- One group watches the video without distractions while the other group watched the video with distractions.

Lesson 2: Texting While Driving (miniSim driving day)

- Drivers receive text while driving MiniSim.
- Students compile class data on swerving due to distracted driving.

- Data graphed similarly to compare texting and driving to the distracted viewing activity.

Lesson 3: Egg Crash

- Students engineer model cars designed to keep an egg safe during a collision by increasing impact time.

Lesson One: Distracted Viewing Activity

1. **Grade Level:** 6-8
2. **Science Topic:** The effects of distraction on attention.
3. **Time Requirement:** 40 minutes
4. **Objectives:**
   - i. Inquiry:
     - iii. To encourage students to connect distractions to decreased performances.
     - iv. To introduce students to the National Advanced Driving Simulator.
     - v. To obtain data that will be compared with data gathered during the second lesson.
   - j. Content addressed:
     - iii. Next Generation Science Standards
       - 1. Crosscutting concepts
         - *a. Cause and Effect*
         - *b. Patterns*
       - 2. Science and Engineering Practices
         - *a. Asking Questions*
         - *b. Analyzing and Interpreting Data*
         - *c. Engaging in Argument from Evidence*
         - *d. Using mathematics*
         - *e. Using Models*
   - k. Possible Misconceptions:
     - iii. Multitasking does not decrease performance.
     - iv. Distractions only affect some individuals who have not had enough practice with them.
   - l. Possible Application:
     - iii. Students will be more informed about the effects of distraction on completion of any activity.
       - 1. Students may use this information when they are studying for exams in college.
5. **Assessment:**
   - i. Students may analyze data and/ or visually represent the statistics as homework for this lesson.
6. **Materials:**

i. Electronic device that can be used to play videos
   iii. This device may also be used for data collection/ analysis.
j. Note cards for student responses
k. Optional:
   iii. Teacher can choose a relevant video and prepare questions for that video.
      1. Can use video to tie in other concepts.

7. Teacher Preparation:

i. Teacher must choose a relevant video and compose questions about the video for students to answer.
   iii. Questions should have a range of difficulty, so "distracted" students will be able to acquire a few answers.

8. Safety/Management issues and special needs adaptations:

i. Epileptic students may experience seizures when some movies are played.
j. Subtitles should be used for students with limited hearing abilities.

9. Differentiation:

i. Can alter questions for video to require more or less attention to the video.
j. Choose videos with closed captioning for students who have trouble interpreting speech.
k. Teacher can allow less advanced students to record questions before video commences, or give students copies of questions for video.

10. Lesson Progression:

i. Teacher led discussion concerning the National Advanced Driving Simulator (NADS).
   iii. This will give students context for when the simulator is brought to the school.
   iv. The teacher may ask the following example questions about NADS. The questions are accompanied by their answers.
      1. What is NADS?
         a. Answer: NADS is a University of Iowa research facility that houses the most advanced (highest fidelity) public driving simulator on the earth. The only other comparable simulator is owned by Toyota. The research facility was constructed using public funds, but it is currently operated on public and private research contracts.
      2. How much did the large simulator cost in order to build?
         a. Answer: The large simulator costs 80 million dollars to build
      3. Why would someone build such a simulator?
         a. Answer: The simulator is used in a variety of different research projects that involve driving. The contracts range from testing the effects of various pharmaceuticals on a person's ability to drive to testing the reactions of people to self-driving cars.
      4. How much does the electricity cost to run the simulator for one hour?
         a. Answer: $1,000- The teacher may compare this cost to the cost of driving a normal car for one hour.
j. Teacher led discussion about the effects of distraction on attention.
   iii. Possible discussion questions
      1. Does anyone consider themselves to be good at multi-tasking?
      2. Is it harder to do homework while watching television?
      3. Can anyone rub their stomach while patting their head?
k. Instructions for distracted watching activity.
   iii. Teacher should divide students into teams.
      1. One team will be the "distracted" team.
      2. The other team will be the "non-distracted" team.
   iv. Instructions for the "distracted" team.

1. Students will watch video while trying to maintain a conversation.
2. Teacher may designate a few students on the team to be "distractors."

v. Instructions for the "non-distracted" team.

1. Students will focus exclusively on the video.

l. Student Prediction

iii. Teacher should ask students which group of students will be able to answer more questions accurately and solicit explanations.

1. Possible questions:
   a. Which group will answer questions accurately?
   b. What individual students will be able to answer the most questions accurately?
   c. How many more questions will be answered accurately by the team who answers the most questions correctly?

m. Exposure to Questions

iii. Teacher may choose to expose students to questions before watching the video.

1. Teacher may also choose to allow recording of the questions.

iv. Teacher should ensure that all students understand questions.

1. Students can be asked to explain questions to less advanced peers.

n. Viewing of Video

iii. Teacher may choose to separate groups while viewing the video.

1. Can send one team out of room, or put teams on opposite ends of room.
2. The "distracted" team should be told once again that they are to carry on a conversation while viewing the video.
3. Teacher may choose to sit with this group during the video in order to aide in distracting them by facilitating a discussion.

iv. Teacher may choose to compose their own questions and show a video of their choosing. Teachers may also use the following suggested video concerning STEM Careers.

1. Suggested Video Title: I Am A Scientist - STEM Education and Life Science Careers
   a. URL: https://www.youtube.com/watch?v=HtBll53jMcM&feature=youtu.be

v. Teacher may also choose to not allow students to discuss questions or video in order to gather more data points in the subsequent section.

o. Student Assessment After Video

iii. Students may answer questions about video alone, or as a group.

1. Can have students answer on note cards.
2. Having students answer questions alone allows for more data to be gathered and subsequently analyzed.

iv. Teacher may use the suggested questions, or questions of their own creation.

1. Suggested Questions for Suggested Video:
   a. What's the name of the school that's primarily represented in this video?
   b. What state is represented in the video?
   c. Name at least three STEM careers/areas mentioned.
   d. What's the name of the video?
   e. What was "step one" shown in the video?

v. Teacher should gather student answers, or have students record how many questions they answered correctly and what group they were in.

p. Data Analysis

iii. Teacher should have students collect data and store it in a table.

1. Example Data Table

11. Scores for Distracted Group	12. Scores for Non-Distracted Group
13. 1	14. 4
15. 2	16. 5
17. 4	18. 4
19. 3	20. 4
21. 2	22. 4
23. 4	24. 5
25. 1	26. 2
27. 1	28. 3
29. 1	30. 4
31. 2	32. 1
33. 2	34. 5
35. 2	36. 5
37. 3	38. 4
39. 1	40. 4
41. 1	42. 3
43. 2	44. 3
45. 2	46. 1
47. 2	48. 1

ii. Teacher should instruct students to calculate various statistics about the gathered data.
   1. Suggested Statistics to Calculate and Formula
      a. Average (Mean) for each Team

i. Formula: X= Number of correct answers for students N= Number of students on team. X

$$\overline{X} = \frac{\sum X}{N}$$

b. Standard Deviation:

i. Formula: X= Number of correct answers for students N= Number of students on team

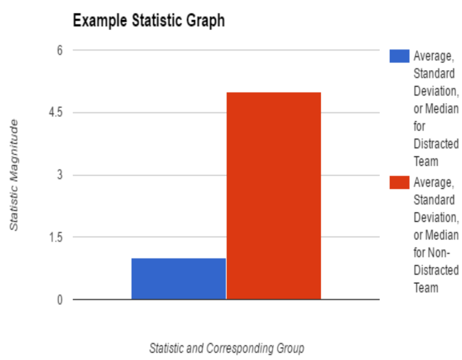
$$SD = \sqrt{\frac{\sum (x - \bar{x})^2}{N-1}}$$

c. Median for each team: The median is the number in the center of a list composed of the scores ranked numerically.

iii. Teachers may have students graphically represent their data and statistics.

1. Can use a bar graphs to compare means, standard deviations, and modes for each team.

a. Example Graph



2. Can use a histogram that shows where different students fall relative to other students with regard to their scores and teams.

a. Example Graph:

i. Teacher led wrap-up discussion.

i. The teacher will lead a discussion on the interpretation of the collected and analyzed data.

1. Suggested Questions

a. What do the statistics tell us about distraction?
b. Why would distraction impair performance?
    i. What organ systems are involved?
c. Where is multitasking common in society?

Lesson Two: Texting While Driving (miniSim driving day)

1. **Grade Level:** 6-8
2. **Science Topic:** The effects of distraction on attention.
3. **Time Requirement:** 80 minutes, two 40 minute class periods
4. **Objectives:**
   c. Inquiry:
      i. To encourage students to construct an answer to the question, "How dangerous is distracted driving?"
      ii. To promote student understanding of statistics.
      iii. To encourage students to consider different factors that affect the level to which texting and driving is dangerous.
   d. Content addressed:
      i. Next Generation Science Standards
         1. Crosscutting Concepts
            a. Patterns
            b. Cause and Effect
      ii. Science and Engineering Practices
            a. Asking Questions
            b. Analyzing and Interpreting Data
            c. Engaging in Argument from Evidence
            d. Using mathematics and computational thinking.
            e. Obtaining, evaluating, and communicating information.
            f. Constructing Explanations
   e. Possible Misconceptions:
      i. Texting and other distractions do not have significant effects on attention.
      ii. Multi-tasking does not decrease performance on either task.
      iii. Texting and driving is only dangerous for people who are slow texters.
   f. Possible Application:
      i. Students will see how texting affects their driving ability. This may discourage texting and driving in the students' futures.
5. **Assessment:**
   c. Students may analyze data collected from the miniSim simulator as an assessment for this lesson.
6. **Materials:**
   c. MiniSim Simulator (Supplied by NADS)
   d. Computer/ device for data analysis.
7. **Teacher Preparation:**
   c. Briefly introduce miniSim technology
   d. What students will be expected to do
   e. How students are expected to behave
   f. Setup area in classroom for miniSim
8. **Safety/Management issues and special needs adaptations:**
   c. Possible nausea from the simulator.
   d. Damage to miniSim if improperly handled
   e. Pedals may be controlled by teacher for students with limited leg/foot mobility
9. **Differentiation:**
   c. Teachers may provide an electronic form that analyzes the data as it is collected.
      i. This form could also graphically represent the data for a student.

d. Teachers may assign more difficult graphic representations to more advanced students, or assign easier graphic representations to less advanced students.

10. Lesson Progression:

c. Discussion of Texting and Driving/ Instructions for Simulator
   i. Instructor asks students probing questions about distracted driving.
      1. Suggested Questions:
         a. How dangerous is texting and driving?
         b. Have you ever seen anyone text and drive?
         c. Is texting more dangerous than completing other tasks while driving?
   ii. Instructor asks students to make prediction about results obtained from the simulator.
      1. Will students swerve more when texting? Why?
      2. Which students will be able to safely text while driving?
   iii. NADS personnel give instructions to students about what to do while driving the simulator.
d. Simulator Driving
   i. Students drive the simulator.
      1. Teacher should foster discussion about the different statistics that are produced by the simulation.
      2. Students should discuss the accuracy of the simulation.
         a. Is it similar to driving in the real-world?
         b. How might results differ if the same exercise was completed with a real car?
   ii. Students should gather data generated by the simulation.
      1. Data will be analyzed in the same fashion as the previous activity.

iii. If the simulator is not available, the following example data set may be used.

1. Example Data Set:

11. Non-Texting Swerving (ft)	12. Texting Swerving (ft)
13. 0.22	14. 1.52
15. 0.83	16. 1.11
17. 0.48	18. 1.06
19. 0.49	20. 0.52
21. 0.36	22. 0.63
23. 0.3	24. 0.47
25. 0.49	26. 0.42
27. 0.33	28. 0.48
29. 0.18	30. 0.63
31. 0.47	32. 0.69
33. 0.19	34. 0.48
35. 0.3	36. 0.38
37. 0.43	38. 0.8
39. 0.66	40. 0.68
41. 0.54	42. 0.87
43. 0.28	44. 1.08

c. Data Analysis and Representation

i. Students analyze data/ produce statistics on the data set.

1. Students will calculate the mean, median, and standard deviation for texting and non-texting data collected.

a. The data should also be visually depicted to ease the comparison to the data from the previous lesson.

b. Formulas

i. Mean: X= Amount of Swerving N= Number of Students

$$\overline{X} = \frac{\sum X}{N}$$

ii. Standard Deviation: X= Amount of Swerving N= Number of Students

iii. Median: The median is the number in the center of the data set when it is arranged by size.

2. Teacher should encourage students to identify any trends that are present.

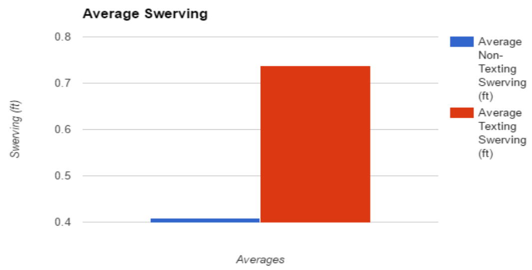
$$SD = \sqrt{\frac{\sum (x - \bar{x})^2}{N - 1}}$$

a. Students will be able to see distraction has negative effects on attention regardless of the task being completed.

3. Example Statistics and Visual Representations

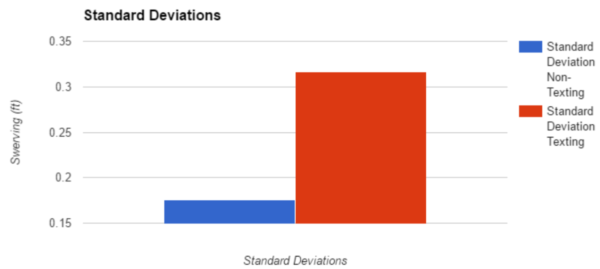
a. Example Means: Texting: 0.74 ft Non- Texting: 0.41 ft

i. Example Graphic Representation:



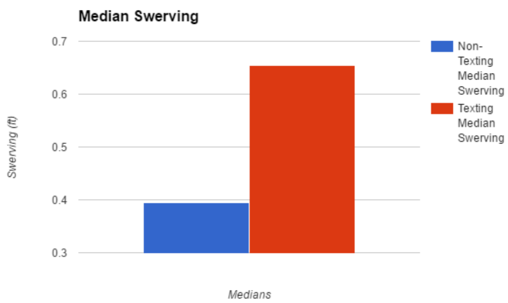
b. Example Standard Deviations: Texting: 0.32 ft Non-Texting: 0.18 ft

i. Example Graphic Representation:



c. Example Medians: Texting: 0.655 ft Non- Texting: 0.395 ft

i. Example Graphic Representation:



d. Discussion of Analyzed Data

i. Class discussion about the implications of the data gathered and analyzed.

1. Guiding Questions:

a. Can students identify any patterns?
b. Would students ban texting and driving based on the data collected?
c. How dangerous is texting and driving?
d. Would students ride in a car driven by any of their texting classmates based on individual results?

e. Reflective Discussion
   i. Reflection on Process
      1. The teacher may lead a discussion about the following questions.
         a. Are there any problems with the gathered data?
         b. Is there strong enough evidence to warrant legislation on distracted driving?
         c. Is it personally dangerous for me to text and drive?
      2. Students may also answer the aforementioned questions in essay form as homework for this activity.

Lesson Three: Egg Crash

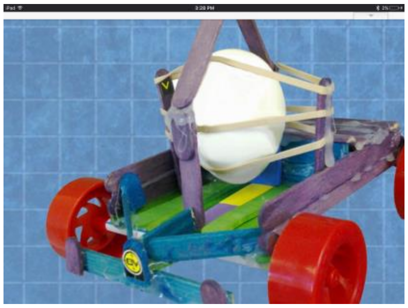
1. **Grade Level:** 5th-9th
2. **Science Topic:** Newton's First Law
3. **Time Requirement:** 120 minutes, three 40 minute class periods
4. **Objectives:**
    a. Inquiry:
        i. Students will be able to comprehend and apply fundamental concepts in physics and engineering including crashworthiness, resilience, mass, and momentum by designing, building, and testing crash test cars.
        ii. Students will be able to direct their own learning by implementing the process of experiential education, which will promote the development of investigative problem solving, outside-of-the-box solutions, group decision making, and teamwork skills
    b. Content addressed:
        i. Next Generation Science Standard
            1. Performance Expectations:
                a. *MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects*
                b. *MS-PS2-2.Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.*
            2. Disciplinary Core Idea
                a. *PS2.A Force and Motion*
                    i. *The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.*
                    ii. *All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.*
            3. Crosscutting Concepts
                a. *Data collection*
                b. *Stability and Change*
                c. *Cause and Effect*
    c. Possible Misconceptions:
        i. Students may regard objects at rest as being a natural state in which no forces are acting on the object.
        ii. Students may believe moving objects come to a stop when there is no friction.
    d. Possible Applications:
        i. Students understand how to reduce damage from any impact.
        ii. Students better understand safety features of vehicles
5. **Assessment:**
    a. Students will present their cars and design features, and demonstrate their cars' efficacy.
        i. Guiding Questions/ Suggested Instructions
            1. What features keep the egg safe?
            2. Will your car keep the egg safe for more than one crash?

3. Describe the effects of the design features in terms of forces and motion.

6. **Materials: (for each student/lab group 4)**
    a. 4-8 Wheels
    b. 4-8 Skewers with 1/8" diameter
    c. 4-8 Milkshake straws
    d. 4-8 Craft Sticks
    e. 4-8 Wood cubes
    f. 4-8 Rubber bands
    g. 2 Small sample cups
    h. 1 Hot glue
    i. 1 piece of cardboard to protect work surface
    j. 2-3 Plastic eggs
    k. 2-3 Hard boiled eggs
    l. 1 Downhill ramp (must be controlled across groups)

7. **Safety/Management issues and special needs adaptations:**
    a. Car bases can be prepared in advance of activity for students who require extra time for activity
    b. Skin abrasions from mishandling materials.
8. **Differentiation:**
    a. Consider having TAG students create a table figuring out the Force of the crash by finding the acceleration and the mass.
    b. More advanced students can build a car intended to withstand multiple crashes.
    c. For students who have LD consider having the base of the car made and simulating the activity and data.
9. **Lesson Progression:**
    a. Day One
        i. Discussion of what makes cars safe.
            1. Suggested Questions
                a. Why do cars have airbags?
                b. Has anyone been in a car accident?
                c. How fast must a car be going in order for a collision to be fatal?
                d. What features of cars keep drivers and passengers safe?
        ii. Introduce activity
            1. Building a car which will keep egg from cracking upon collision
            2. Specify ramp dimensions with which cars will be tested
        iii. Discuss mobility requirements of car
            1. Must roll down ramp unassisted
            2. Must remain composed as it rolls
        iv. Split students into groups of four.
            1. Each group will eventually produce one car
        v. Groups plan the design of their car.
            1. Brainstorm ideas
            2. Prototype with materials in class (dependent on availability)
            3. Sketch multiple designs
        vi. Each group turns in one sketch for their design.
            1. Teach now has estimate of materials to provide for Day One
    b. Day Two
        i. Teacher introduces available materials.

- ii. Groups reflect on designs from Day One
    1. Decide on any changes to reflect material provided
- iii. Groups build cars
    1. Teacher does not direct students as to the purpose of each material
    2. Example car



- iv. Optional: Discussion of how cars will be assessed during the testing.
    1. Suggested Categories
        - a. Aesthetic appeal
        - b. Size, length, or number of cracks
        - c. Durability

c. Day Three
- i. Discussion of assessment categories
- ii. Last minute preparation before testing
- iii. Presentation of cars
    1. Each group presents their car's features and their reasoning
- iv. Predictive vote on winning car
    1. Can be informal or formal voting
    2. Votes can be individual or as a group
    3. Optional: Require students to explain their reasoning.
- v. Car testing
    1. Individual teams publicly test their car.
        - a. Students may record observations during the test
- vi. Reflective discussion on results of car tests.
    1. Class compares results of tests with predictions.
    2. Suggested Questions
        - a. What features were common amongst well performing cars?
        - b. Are there similarities between the model cars and cars on the road?
        - c. If you could build another car, which features would you include?