3

Playground Forces

NGSS EARLY IMPLEMENTERS

WestEd

A Collaboration of the K–12 Alliance @ WestEd,
Aspire Public Schools, Galt JUSD, High Tech High,
Kings Canyon USD, Lakeside USD, Oakland USD, Palm Springs USD,
San Diego USD, Tracy USD, Vista USD,
Achieve, and the California Department of Education

with funding from the
S.D. Bechtel, Jr. Foundation
Hastings-Quillin Fund

A project of CA NGSS K–8 Early Implementation Initiative.

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Introduction

The California K–8 NGSS Early Implementation Initiative was developed by the K–12 Alliance at WestEd with close collaborative input on its design and objectives from the California State Board of Education, the California Department of Education, and Achieve. This project was designed to build local education agency (LEA) capacity to fully implement the Next Generation Science Standards (NGSS) as a core subject in the elementary grades (K–5) and as the SBE's preferred integrated model in grades 6–8.

The six-year Initiative provided teachers and administrators with in-depth, content-rich professional development to build leadership capacity and teacher acumen to deliver high-quality 3-dimensional learning for K–8 students. In addition, through collaborations among the K–12 Alliance, Achieve, and others, the LEAs in the Collaborative had opportunities to pilot test new NGSS-aligned tools, processes, assessment item prototypes, and digital and other instructional materials. The LEAs continue to serve as resources for NGSS implementation across California, and in other NGSS-adopting states as well.

This resource presents the conceptual storyline for a unit of instruction at a specific grade level, then focuses on a portion of the storyline called a learning sequence. The learning sequence uses the three dimensions of the NGSS (disciplinary core ideas—DCI; science and engineering practices—SEP; and crosscutting concepts—CCC) to build and deepen student understanding of natural phenomena and design challenges.

Participants in the CA NGSS K–8 Early Implementation Initiative developed and field-tested the lessons in the learning sequence.

Overview

After completing this unit, students will never look at recess or physical education the same way again. The anchoring phenomenon for this unit is objects move in different ways during physical activities on the playground. This unit is the first half of the third grade Physical Science standards and addresses the first two Performance Expectations only. In this unit, students identify forces and that forces have strength and direction. While exploring the playground, students observe the action of contact forces by investigating how balanced and unbalanced forces cause motion as well as how speed and direction changes are caused by the strength and the direction of the force. Students also incorporate their observations of patterns to predict the future motion of objects when a force is applied. The students complete this unit by using their knowledge of force and motion on the playground to design a new playground structure or activity.

The Performance Expectations addressed in this unit are:

3-PS2-1 Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. *[Clarification Statement: Examples could include an unbalanced force on one side of a ball can make it start moving; and, balanced forces pushing on a box from both sides will not produce any motion at all.] [Assessment Boundary: Assessment is limited to one variable at a time: number, size, or direction of forces. Assessment does not include quantitative force size, only qualitative and relative. Assessment is limited to gravity being addressed as a force that pulls objects down.]*

3-PS2-2 Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion. *[Clarification Statement: Examples of motion with a predictable pattern could include a child swinging in a swing, a ball rolling back and forth in a bowl, and two children on a see-saw.] [Assessment Boundary: Assessment does not include technical terms such as period and frequency.]*

3-5-ETS1-1 Define a simple design problem reflecting a need or want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

Learning Sequence Narrative

The Learning Sequence Narrative briefly describes what students do in each lesson and links the learning between the lessons as a conceptual storyline. At the end of each learning sequence, students make connections to their understanding of the investigative phenomenon and/or the identified problem (and to the anchoring phenomenon when appropriate).

The anchoring phenomenon for the learning sequence is objects move in different ways during physical activities on the playground.

Students figure out this phenomenon by:

Science and Engineering Practices (SEPs)

Asking Questions and Defining Problems

- Ask questions that can be investigated ~~and predict reasonable outcomes based on patterns such as cause and effect relationships~~.
- Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.

Developing and Using Models

- Collaboratively develop and/or revise a model based on evidence ~~that shows the relationships among variables for frequent and regular occurring events~~.
- Develop and/or use models to describe and/or predict phenomena.
- Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.
- Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.

Planning and Carrying Out Investigations

- Evaluate appropriate methods and/or tools for collecting data.
- Make observations ~~and/or measurements~~ to produce data to serve as the basis for evidence for an explanation of a phenomenon or to test a design solution.
- Make predictions about what would happen if a variable changes.

Analyzing and Interpreting Data

- Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships.
- Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.
- Analyze data to refine ~~a problem statement or~~ the design of a proposed object, tool, or process.

Constructing Explanations or Designing Solutions

- Construct an explanation of observed relationships.
- Use evidence (e.g., ~~measurement~~, observations, patterns) to construct or support an explanation or design a solution to a problem.
- Apply scientific ideas to solve design problems.
- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.

Engaging in Argument from Evidence

- Construct and/or support an argument with evidence, data, and/or a model.

Obtaining, Evaluating, and Communicating Information

- Communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts.

Disciplinary Core Ideas (DCIs)

PS2.A: Forces and Motion

- Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion.
- The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it.

PS2.B: Types of Interactions

- Objects in contact exert forces on each other.

ETS1.A: Defining and Delimiting Engineering Problems

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.

ETS1.B: Developing Possible Solutions

- At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.

Crosscutting Concepts (CCCs)

Patterns

- Similarities and differences in patterns can be used to sort, classify, communicate, ~~and analyze simple rates of change~~ for natural phenomena and designed products.
- Patterns of change can be used to make predictions.

Cause and Effect

- Cause and effect relationships are routinely identified, tested, and used to explain change.

Influence of Engineering, Technology, and Science on Society and the Natural World

- Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands.

The following narrative is based on the conceptual flow found at the end of this section.

Lesson 1: Movement on the Playground

Identified Problem: A school can't reopen the playground until it receives a design for a new playground structure.

This lesson builds on students' observation that objects move on a playground (anchoring phenomenon) and introduces students to a real-world problem: the scenario of a playground that needs to be redesigned. Students discuss why playgrounds are important, make observations of movement on the current playground, and use those observations to determine initial criteria to meet the design challenge of creating a new playground. They also determine initial investigation questions to gather evidence to support their design. Students explore forces and motion with such questions as: What is the movement? What caused it to move? How does it apply to our identified problem?

Lesson 2: Forces Move Objects

Investigative Phenomenon: A basketball on the playground moves when it is thrown.

This lesson builds on students' prior knowledge shared in Lesson 1: Movement on the Playground. In this lesson, students explore the three questions from Lesson 1 as they investigate the cause and effect of various characteristics of forces using the playground game of basketball. Students use a model to show that forces have strength and direction. Students are also introduced to the force of gravity. They discuss cause-and-effect relationships to move a basketball and look for patterns in motion.

Lesson 3: Patterns in Motion

Investigative Phenomenon: A kicked soccer ball on the playground didn't make it all the way into the goal.

In Lesson 2: Forces Move Objects, students created models to show balanced and unbalanced forces based on the knowledge gained through basketball experiences. In this lesson, students build on these fundamental understandings of force and motion and apply them to a soccer ball. They continue to explore the three questions from Lesson 1: Movement on the Playground as they analyze and interpret data about how strength of the force impacts the distance the soccer ball moves. They apply the patterns of motion and cause-and-effect relationships to predict team players and their success for a new soccer game for the new playground.

Lesson 4: Balanced and Unbalanced Forces

Investigative Phenomenon: Small children on the playground win a tug-of-war challenge against a group of bigger children.

In Lesson 2: Forces Move Objects and Lesson 3: Patterns in Motion, students continued to build on the fundamental understandings of force and motion using balls. In this lesson, the students work with a non-ball example (tug-of-war) to continue to think about the cause and effect of balanced and unbalanced forces on an object as well as the strength and direction of the force. They also look for patterns in motion. They apply these understandings to the design of the playground.

Lesson 5: Playground Design

Identified Problem: A school can't reopen the playground until it receives a design for a new playground structure.

This lesson builds on the student data, knowledge, and explanations of force and motion gained in the prior lessons. This is the culminating lesson in the learning sequence. This lesson introduces the concepts of engineering design and the use of forces and motion to solve a problem. The previous lessons had students constructing explanations and models about the cause and effect of forces by observing patterns and collecting data from their investigations. Students will use this information to design and construct a new playground activity or piece of equipment to help solve the problem of replacing an old, unusable playground structure.

Learning Sequence 3-Dimensional Progressions

SEP PROGRESSION	
Asking Questions and Defining Problems	
Lesson 1	Students ask questions that can be investigated and are given a simple design problem that can be solved through the development of an activity or structure. They identify several initial criteria for success.
Lesson 5	Students continue to use this practice and add in constraints for materials and time.
Developing and Using Models	
Lesson 2	Students build on their K–2 knowledge of developing and using models to collaboratively produce a model as the basis for evidence of the force of gravity.
Lesson 4	Students continue to build their understanding of this practice to show relationships and connections between direction and strength of forces. Students continue to use this practice as they did in Lesson 2 with a focus on using their models as evidence for balanced and unbalanced forces.
Lesson 5	Students continue to use this practice and use their models to develop a prototype to describe and display their activity or structure. They also use their models to show the cause-and-effect relationships or interactions in their designed prototype.
Planning and Carrying Out Investigations	
Lesson 4	Students build on their K–2 knowledge of conducting an investigation to evaluate appropriate methods to collect data to serve as a basis for evidence for their explanation of the balanced and unbalanced forces in the tug-of-war activity. They also work collaboratively to make predictions about what might happen if the variable changes from number of students on each side to the size of the students.

Learning Sequence 3-Dimensional Progressions (continued)

SEP PROGRESSION (continued)	
Analyzing and Interpreting Data	
Lesson 3	Students build on their K–2 abilities to record information by comparing and contrasting data collected by different groups to discuss the patterns they noticed and if those patterns indicate a relationship between the strengths of a force and the distance traveled.
Constructing Explanations and Designing Solutions	
Lesson 4	Students apply scientific ideas to design solutions. They construct an explanation of the observed relationships and use evidence to support that explanation.
Lesson 5	Students apply the scientific ideas they have learned in these lessons to the design problem. They design their solution and compare other groups' solutions to the problem based on how well they meet the criteria and constraints of the designed solution.
Engaging in Argument from Evidence	
Lesson 2	Students construct and/or support an argument using evidence, data, and a model.
Lesson 5	Students apply the scientific ideas they have learned in these lessons to the design problem. They design their solution and construct an argument with data and a model. They compare other groups' solutions to the problem based on how well they meet the criteria and constraints of the designed solution.
Obtaining, Evaluating, and Communicating Information	
Lesson 5	Students communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts.

DCI PROGRESSION	
Prior Learning	The intent is to use the 3-5-ETS1 Performance Expectations and its associated DCIs (ETS1.A, and ETS1.B), but if your students have no exposure/history with engineering design at this point, then refer to the K-2-ETS1 Performance Expectations for this initial challenge.
Lesson 1	Builds on Kindergarten (PS2.A) Each force acts on one particular object and has both strength and a direction. Objects in contact exert forces on each other. (PS2.A, PS2.B) The success of a designed solution is determined by considering the desired feature of a solution. (ETS1.A)

Learning Sequence 3-Dimensional Progressions (continued)

DCI PROGRESSION (continued)	
Lesson 2	Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on an object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. Objects in contact exert forces on each other. (PS2.A, PS2.B) Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (ETS1.A) At whatever stage, communicating with peers about proposed solutions is an important part of the design process and shared ideas can lead to improved designs. (ETS1.B)
Lesson 3	Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on an object. Forces that do not sum to zero can cause changes in the object's distance ~~speed or direction~~ of motion. The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (PS2.A)
Lesson 4	An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. The patterns of an object's motion in various situations can be observed ~~and measured~~; when that past motion exhibits a regular pattern, future motion can be predicted from it. (PS2.A)
Lesson 5	Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on an object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (PS2.A)

CCC PROGRESSION	
Patterns	
Lesson 2	Students identify patterns in their collected data and use these patterns to make predictions as evidence of the strength and direction of forces.
Lessons 3 and 4	Students identify patterns of change and use them to make predictions.
Cause and Effect	
Lesson 1	Students build on their understanding that events have causal relationships and use these relationships to identify changes in motion.
Lesson 2	Students identify causal relationships and use these relationships to explain the force of gravity.

Learning Sequence 3-Dimensional Progressions (continued)

CCC PROGRESSION (continued)	
Cause and Effect	
Lesson 3	Students identify causal relationships and use these relationships to explain strength and direction of force.
Lesson 4	Students identify causal relationships of balanced and unbalanced forces to explain the cause of motion.
Lesson 5	Students identify causal relationships as they design their playground equipment and use those relationships to explain force and motion.

Assessment

The Grade 3: Playground Forces unit provides multiple and ongoing strategies for teachers to assess student understanding as they progress toward mastery of Performance Expectations. These include:

- Possible assessment opportunities are marked with a red flag (▶). Throughout the lessons, these are often formative assessments. Sometimes the Evaluate phase might serve as a summative assessment.
- Rubrics are provided to assess student understanding in Lesson 2: Forces Move Objects, Lesson 3: Patterns in Motion, and Lesson 5: Playground Design.
- Science notebooks are used in each lesson. Students' responses in their science notebook allow you to informally assess student progress.
- Expected Student Responses (ESRs) are used throughout the unit to guide you in the types of responses students may provide. The actual student responses can be compared to the ESR as a formative assessment of student understanding at that point in time. Note: ESRs are not the only possible student responses, and you should not provide the ESRs to the students.
- The 5E instructional model provides an opportunity for you to assess students' prior knowledge in the Engage phase, to assess tentative explanations in the Explain phase, and to measure student understanding of the full lesson concept in the Evaluate phase.

References

NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. DOI: https://doi.org/10.17226/13165. National Research Council; Division of Behavioral and Social Sciences and Education; Board on Science Education; Committee on a Conceptual Framework for New K–12 Science Education Standards. National Academies Press, Washington, DC.

Grade 3 Playground Forces Conceptual Flow

Anchoring Phenomenon

Objects move in different ways during physical activities on the playground.

Balanced and unbalanced forces act on an object.

Investigative Phenomena or Identified Problem

A school can't reopen the playground until it receives a design for a new playground structure.	A basketball on the playground moves when it is thrown.	A kicked soccer ball on the playground didn't make it all the way into the goal.	Small children on the playground win a tug-of-war challenge against a group of bigger children.	A school can't reopen the playground until it receives a design for a new playground structure.
PS1.A, PS2.A	PS1.A, PS2.A	PS2.A	PS1.A, PS2.A	PS1.A, PS2.A
Playground games and equipment demonstrate the concepts of force and motion.	Forces (including gravity) have strength and direction. Objects have multiple forces acting on them.	An unbalanced force can cause changes in direction or distance. Patterns can be used to predict future motion.	Balanced and unbalanced forces act on an object with strength and direction. Objects in contact exert forces on each other.	Playground designs are based on force and motion concepts that meets criteria and constraints. Designs are compared and improved.
ETS1.A				ETS1.A, ETS1.B
Asking questions and defining problems	Developing and using models	Analyzing and interpreting data	Developing and using models	Constructing explanations and designing solutions
	Engaging in argument from evidence		Constructing explanations and designing solutions	Obtaining, evaluating, and communicating information
			Planning and carrying out investigations	Engaging in argument from evidence

Patterns

Cause and Effect