K

Pushes and Pulls

NGSS EARLY IMPLEMENTERS

WestEd

A Collaboration of the K-12 Alliance @ WestEd,
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Acknowledgments

Writers

Karal Blankenship, San Diego USD, Kindergarten teacher

Priscella Barcellos, Lakeside USD, Kindergarten teacher

Karen Cerwin, K–12 Alliance Regional Director, WestEd

Ann Zelaya, Palm Springs USD, Kindergarten teacher

Readers

Kimberly Allard, San Diego USD, Science Enrichment Teacher

Debbie Gordon, Palm Springs Unified School District, Teacher on Special Assignment (TOSA)

Field Test Teachers

Stephanie Loutzenhiser, Galt USD, Kindergarten teacher

Maggie Jordan, Palm Springs USD, Kindergarten teacher

Katherine Worrell, Vista USD, Kindergarten teacher

Catie Lopez, Vista USD, Kindergarten teacher

Reviewers

Achieve Science Peer Review Panel

Table of Contents

Grade K Pushes and Pulls

Anchoring Phenomenon: Objects do not move on their own.

Introduction

Lessons

Table of Contents

Introduction

The California K–8 NGSS Early Implementation Initiative, developed by the K–12 Alliance at WestEd with close collaborative input on its design and objectives from the State Board of Education, the California Department of Education, and Achieve is a fast-start demonstration project 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 four-year Initiative provides 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 have opportunities to pilot test new NGSS-aligned tools, processes, assessment item prototypes, and digital and other instructional materials. The LEAs 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

The anchoring phenomenon for this unit is "Objects do not move on their own." In this unit, students investigate ways to move objects and describe their movement: pushes can be described by their strength and direction; pulls can be described by strength and direction; and when two objects collide, they will change direction or push against each other and stop.

The Performance Expectations addressed this unit are:

K-PS2-1	Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.
K-PS2-2	Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.
K-2-ETS1-1	Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

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 between the phenomenon/identified problem and the anchoring phenomenon.

The anchoring phenomenon for the learning sequence is "Objects do not move on their own." This learning sequence uses a soccer game as a context for putting objects into motion. In Lesson 1, pushes and pulls are explored by moving motionless objects in a box. This leads to the understanding of the investigative phenomenon "Game balls do not move on their own." In Lesson 2, students are presented with the coach's problem of how to move the soccer materials to the field. Developing a design for moving the materials in one trip leads to the identified problem "Soccer materials do not move on their own to the field." Lesson 3 explores the investigative phenomenon of "Discs move different distances" through playing a mini-shuffleboard game. Connections are made between the strength of a push and the distance a disc travels. This strength of the force contributes to understanding the cause and effect of pushes. Lesson 4 explores the investigative phenomenon of how "Windy days change how the ball moves in soccer." This connects to kindergarten earth science observations of weather. Lesson 5 explores the investigation phenomenon of "A ball thrown against a wall changes directions." Students play a game of wall ball and a game of mini wall ball to understand collisions, stopping, and changes in direction. Lesson 6 returns to the soccer game by planning a solution to the identified problem of "More goals are made in soccer with a plan." This is a problem that requires all the concepts presented in the Learning Sequence to design the best solution for the problem.

Science and Engineering Practices (SEPs)

Asking Questions and Defining Problems

Asking questions and defining problems in K–2 builds on prior experiences and progresses to simple descriptive questions that can be tested.

- Ask questions based on observations to find more information about the natural and/or designed worlds(s).
- Define a simple problem that can be solved through the development of a new or improved object or tool.

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations that provide data to support explanations or design solutions.

- With guidance, plan and conduct an investigation in collaboration with peers.

- Evaluate different ways of observing and/or measuring a phenomenon to determine which way can answer a question.
- Make observations (firsthand or from media) and/or measurements to collect data that can be used to make comparisons.
- Make predictions based on prior experiences.

Analyzing and Interpreting Data

Analyzing data in K–2 builds on prior experiences and progresses to collecting, recording, and sharing observations.

- Record information (observations, thoughts, ideas).
- Use and share pictures, drawings, and/or writings of observations.
- Compare predictions (based on prior experiences) to what occurred (observable events).
- Analyze data from tests of an object or tool to determine if it works as intended.

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in K–2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.

- Use information from observations (firsthand and from media) to construct an evidence-based account for natural phenomena.
- Use tools and/or materials to design and/or build a device that solves a specific problem ~~or a solution to a specific problem~~.
- Generate and/or compare multiple solutions to a specific problem ~~or a solution to a specific problem~~.

Obtaining, Evaluating, and Communicating Information

- Communicate information or design ideas and/or solutions with others in oral and/or written forms using models, drawings, writing, or numbers that provide detail about scientific ideas, practices and/or design ideas.
- Obtain information using various texts, text features (e.g., heading, tables of contents, glossaries, electronic menus, icons) and other media that will be useful in answering a scientific question and/or supporting a scientific claim.

Disciplinary Core Ideas (DCIs)

PS2.A: Forces and Motion

- Pushes and pulls can have different strengths and directions.
- Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.

PS2.B: Types of Interactions

- When objects touch or collide, they push one another and can change motion.

PS3.C: Relationship Between Energy and Forces

- A bigger push or pull makes things speed up or slow down more quickly.

ESS2.D: Weather and Climate

- Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time.

ETS1.A: Defining and Delimiting Engineering Problems

- A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions.
- Asking questions, making observations, and gathering information are helpful in thinking about problems.

ETS1.B: Developing Possible Solutions

- Designs can be conveyed through sketches, drawings or physical models. These representations are useful in communicating ideas for a problem's solution to other people.

Crosscutting Concepts (CCCs)

Patterns

- Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.

Cause and Effect

- Events have causes that generate observable patterns.
- Simple tests can be designed to gather evidence to support or refute student ideas about causes.

The following Learning Sequence Narrative is based on the conceptual flow found at the end of this section.

Lesson 1: Exploration Box

Investigative Phenomenon: Game balls do not move on their own.

This lesson introduces students to a real-world context for how pushes and pulls are used to make objects (balls) move in soccer and other games.

In this first lesson, the investigative phenomenon (a motionless ball) is used to generate ideas and ask questions about the ways to move a soccer ball. (SEP) Students' prior knowledge about how balls are made to move in soccer is used as a motivation for the discussion. (DCI) (CCC)

Once the motionless ball is moved, the investigation uses the motionless objects in the exploration box to figure out different methods for moving or stopping objects. (DCI, SEP) Movement or stopping of any object (effect) has a cause that can be described as a push or pull. (CCC) This learning experience offers opportunities for the teacher to support student use of words describing a push and pull that causes movement or stopping of movement. (Embedded vocabulary)

Understanding the investigative phenomenon "Game balls do not move on their own" will lead to understanding the anchoring phenomenon "Objects do not move on their own." Realizing that the objects in the box are moved or stopped by pushes or pulls leads to an understanding of motion and the academic words used to describe the force. The lesson concludes with a class assessment opportunity by completing the "What do we know about moving objects such as soccer balls?" in the kindergarten science notebook. (DCI)

Lesson 2: Pullapalooza

Identified Problem: Soccer equipment cannot move to the field on its own.

At the conclusion of Lesson 1, students were presented with an engineering challenge. Soccer materials were displayed on the floor and students generated questions about what they needed to know to move the materials to the field. Students start this lesson with their list of questions. The students are then presented with some constraints to solve the problem: a set of materials that can be used for the move and the idea that their solution should require only one person making one trip. Plans are discussed, and partners develop a model of their solution on a poster to share with the class. (SEP) Class discussions focus on how different structures in the design cause objects to move differently. (CCC)

Designing a solution leads to a deeper understanding of how pushes and pulls are used to design solutions to problems.

The concepts of cause and effect related to pushes and pulls contributes to the understanding of the anchoring phenomenon of how pushes and pulls are used to move motionless objects such as soccer equipment to the field.

Lesson 3: Cruising Discs

Investigative Phenomenon: Discs move different distances.

At the conclusion of Lesson 2: Pullapalooza, students generated a list of other ideas they needed to figure out how to make a motionless ball score a goal. This lesson deepens their understanding of movement by describing the strength of a push. (DCI) The investigative phenomenon "Discs move different distances" is observed in a video of shuffleboard. Students

play a mini-shuffleboard game where the cause and effect of different-strength pushes result landing in different sections of the shuffleboard. They gather data about the push used and the distance traveled. (CCC) (SEP) Understanding that different pushes result in different distances traveled by a disc in the shuffleboard deepens understanding of the anchoring phenomenon that motionless objects won't move on their own. Movement from pushes show patterns to predict distances.

Lesson 4: Huff, Puff, and Move the Ball

Investigative Phenomena: Windy days change how the ball moves in soccer.

Lesson 3: Cruising Discs explored the force of the pushes used in a mini-shuffleboard game. In this lesson, understanding the strength of a push is deepened by changing the cause of the push. (CCC) This concept is introduced through a video that shows the phenomenon of high winds pushing on a ball. (CCC)

While we cannot see wind, we can see what wind does to objects. To explore this concept, students blow through two different-sized straws causing a small ball to move at different speeds. (DCI) By collecting and analyzing data, they deepen their understanding of ways to change the strength of a push. (SEP) When playing soccer, a strong wind can push the ball in a different direction.

The second part of this lesson extends the experiment with straw and ball. Students use the science and engineering practice of collaboratively designing and planning an investigation to determine how to change the direction that an object moves as well as changing the strength of the push. (SEP)

Lesson 5: When Two Objects Collide

Investigative Phenomenon: A ball thrown against a wall changes direction.

In the previous lessons, investigative phenomena using explorations with pushes and pulls established that pushes and pulls stop objects or move them in different directions. The force of the push or pull will impact the distance traveled during the movement. (DCI)

In this lesson, the investigative phenomenon is "A ball thrown against a wall changes direction." It explores the question of how to get a ball around defenders in soccer. The activity for the investigation begins by observing how a ball moves in a wall ball game. Understanding how the ball moves in wall ball deepens the concept that when objects collide, the direction of the movement changes in predictable patterns. (DCI)

In this mini-wall ball exploration, a ball is rolled down a ramp to collect data about the effect of a ball colliding with a wall. (SEP) The ramp is used to keep the force of the ball consistent during the investigation. Data will be collected and recorded showing the effect of changing the angle of the ramp has on the collision of the ball with the wall. This data will be used to collaboratively discuss how the changes with the ramp cause predictable patterns of collisions with the wall. This leads to a deeper understanding of the effects and patterns. (CCC)

Wall ball helps build an understanding of how players on a soccer field are used as collision points that can change the direction and strength of a push on a soccer ball. This investigation adds to the knowledge of the anchoring phenomenon of how motionless objects can be made to move.

Lesson 6: Collision Goal!

Identified Problem: More goals are made in soccer with a plan.

In this final investigation, the data collected from observing and recording pushes that change direction in Lesson 5: When Two Objects Collide will be used to collaboratively design a solution or strategy for using collisions to move a ball around an obstruction. Materials available to design or engineer the plan for scoring are familiar materials used throughout the investigations: a ramp, a collision wall, a goal, and a ball. (SEP) (CCC) (DCI)

Students collaboratively plan, test, adjust their plan, and retest leading to the selection of the best plan or solution. Students use what they have figured out in Lesson 1: Exploration Box about pushes and pulls, combined with designing solutions in Lesson 2: Pullapalooza, strategic use of the strength of the force in Lesson 3: Cruising Discs, forces of pushes from wind in Lesson 4: Huff, Puff, and Move the Ball as well as changes due to collisions in Lesson 5: When Two Objects Collide to plan for collisions in the final explanation of how to move a motionless ball using the strength of force and collisions to score a goal in soccer.

An individual plan for scoring is evaluated on understanding how to get a motionless object (soccer ball) to move in predictable ways using the strength of a kick (ramp), placement of players for collisions or stopping motion, and direction of kicks to score goals.

Learning Sequence 3-Dimensional Progressions

SEP Progression

If SEPs are emphasized in a lesson, they are in the foreground. If they support the learning but are not primary to it, they are in the background.

SEP PROGRESSION	
Asking Questions and Defining Problems	
Lesson 1	Students ask questions about how goals are made in soccer.
Lesson 2	Students define the problem of how to get equipment to the soccer field.
Lesson 4	Students generate questions about moving objects with wind.
Lesson 6	Students use questions to refine the problem and design a solution to scoring a goal around objects (obstacles).
Planning and Carrying Out Investigations	
Lesson 1	Students conduct an investigation to figure out how objects move by pushes and pulls.
Lesson 2	Students plan a tool to solve the problem of moving objects.
Lesson 3	Students conduct an investigation to figure out the relationship between the strength of a push and the distance an object travels.

Learning Sequence 3-Dimensional Progressions (continued)

SEP PROGRESSION (continued)	
Planning and Carrying Out Investigations (continued)	
Lesson 4	Students build on their understanding of the strength of a push and collaboratively plan and conduct an investigation of the strength of different pushes on a small ball.
Lesson 5	Students deepen their understanding of planning and conducting investigations by using a model of wall ball to investigate the direction and force of a push.
Lesson 6	Students plan and conduct mini-games of soccer using what they know about collisions and ramps. This lesson is a culmination of understanding the phenomenon of scoring in soccer by designing collisions and ramps for getting around players.
Analyzing and Interpreting Data	
Lesson 1	Students collect observations of how objects are moved by a push or a pull.
Lesson 3	Students compare predictions of how to score points in shuffleboard to collecting data from the mini-shuffleboard game.
Lesson 4	Students use observations of wind on a soccer field to collect data about how wind moves objects.
Lesson 5	Students collect data about how collisions are used in wall ball to change the direction of the ball.
Lesson 6	Students analyze data collected from the strength of pushes in lessons 3 and 4 and collisions in Lesson 5 to design a solution for scoring a goal on a soccer field.
Constructing Explanations and Designing Solutions	
Lesson 1	Students use evidence (observations) to construct an explanation of how things move with a push or a pull.
Lesson 2	Students design and compare solutions to the problem of how to move equipment to the field.
Lessons 3 and 4	Students construct explanations about the relationship between the force and strength of a push.
Lesson 5	Students construct a model of collisions and use it to explain how collisions change direction of movement.
Lesson 6	Students apply what they know about strength of a force and change in direction through collisions to score a goal in soccer.
Obtaining, Evaluating, and Communicating Information	
Lessons	While this practice is not in the foreground of the learning sequence, it is in the background of most lessons where students are asked to communicate scientific information orally and/or in written format by making contributions to the Class Notebook and reading the chart. A list of nonfiction books is included in the lessons and should be read aloud to model obtaining information from books as well as modeling informational writing formats.

Learning Sequence 3-Dimensional Progressions (continued)

DCI PROGRESSION	
Lesson 1	Pushing or pulling on an object ~~can change the speed or direction of its motion and~~ can start or stop it. (PS2.A) Asking questions, making observations, and gathering information are helpful in thinking about problems. (ETS1.A)
Lesson 2	Pushes and pulls can have different strengths and directions (PS2.A) Asking questions, making observations, and gathering information are helpful in thinking about problems. (ETS1.A) Designs can be conveyed through ~~sketches~~, drawings, ~~or physical models~~. These representations are used in communicating ideas for a problem's solution to other people. (ETS1.B)
Lesson 3	Pushes or pulls have different strengths ~~and directions~~. (PS2.A) Pushing or pulling on an object can change the speed or direction of an object and can start or stop it. (PS2.A) A bigger push makes things speed up or slow down more quickly. (PS2.C)
Lesson 4	A push on an object can change the speed or direction of its motion and can start or stop it. (PS2.A) A bigger push makes things speed up or slow down more quickly. (PS2.C) Weather is the combination of sunlight, wind, snow or rain, and temperature in a particular region at a particular time. People measure these conditions to describe and record the weather and to notice patterns over time (ESS2.D)
Lesson 5	When objects touch or collide, they push on one another and can change motion. (PS2.B) Pushing or pulling on an object can change the speed or direction of its motion. (PS2.A)
Lesson 6	Combines PS2.A, 2.B and 2.C A situation that people want to change or create (scoring goals in soccer) can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions (EST1.A) Designs can be conveyed through ~~sketches~~, drawings, ~~or physical models~~. These representations are used in communicating ideas for a problem's solution to other people. (ETS1.B)

CCC PROGRESSION	
Cause and Effect	
Lesson 1	Students explore the cause of movement through pushes or pulls.
Lesson 2	Students observe patterns of movement and consider structure and function to design a plan to move objects to a field for the effect of making the work easier.
Lesson 3	Students identify the cause of a change in the strength of the movement of an object.

Learning Sequence 3-Dimensional Progressions (continued)

CCC PROGRESSION (continued)	
Cause and Effect (continued)	
Lesson 4	Students observe the effect when the wind blows and identify patterns in the change of direction.
Lesson 5	Students identify the causes of change in direction of a ball due to collisions in wall ball.
Lesson 6	Students plan the cause and effect of scoring in soccer by using different pushes of strengths of force, direction, and collisions as part of the plan.
Patterns	
Lessons	The crosscutting concept of pattern is the background in most lessons in order to generalize what is common about objects that move fast, slow, greater or lesser distance, change direction, or stop. These patterns are part of the discussion but not the primary crosscutting concept driving the investigations.

References

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

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Grade K Pushes and Pulls Conceptual Flow

Anchoring Phenomenon

Objects do not move on their own.

Pushes and pulls cause objects to move.

Investigative Phenomena and Identified Problems

Game balls do not move on their own.	Soccer equipment cannot move to the field on its own.	Discs move different distances.	Windy days change how a ball moves in soccer.	A ball thrown against a wall changes direction.	More goals are made in soccer with a plan.
PS2.A	PS2.A, PS3.C	PS2.A, PS3.C, ESS2.D	PS3.B		
Motion can be described. You can push or pull an object to start or stop it.	Pulls can be described by strength and direction.	A bigger push makes things speed up and slow down more quickly. A bigger push makes things go farther.	When objects touch or collide, they push against each other and change motion (change direction). Objects stop when they push against each other.		
	ETS1.A, ETS1.B		ETS1.A, ETS1.B		
Planning and carrying out investigations	Constructing explanations and designing solutions	Planning and carrying out investigations	Analyzing and interpreting data	Developing and using models	Analyzing and interpreting data

Obtaining, evaluating, and communicating information

Patterns

Cause and Effect