UDL Teacher Guide: Beginning Friction

Friction in Everyday Life

Amontons' laws of friction (1699)
(1) Friction is independent of the apparent area of contact
(2) The frictional force F is directly proportional to the normal load W

Driving Question: What if there were no friction?

This unit explores how friction impacts how things move.

Introduction

Using the UDL approach, students actively explore the movement of materials in their world. Friction is one of the forces that affects how things move. Students will learn about friction in multiple ways: from a fictional story to data collection with probes, and from hands-on inquiry investigations to using computer models to show how friction works.

Technology

The technology used in the friction unit is designed to allow students to discover the story told by the data they collect as they investigate friction. A force sensor is used in "Dragging Shoes" to gather data about the amount of force required to move over different surfaces.

Smart graphs allow students to analyze data in a meaningful and supported way. The graphing tools are the same, regardless of the activity.

The technology in UDL does not supplant the teacher. Instead, students are individually supported throughout the unit. One example of this support is that students can highlight the text and the computer will vocalize the words. Definitions for highlighted words (in blue) are also built into the program. A complete glossary for the unit can be found at the bottom each page using the book icon. In some of the units you will also find three robot helpers. These robots help the student understand the material by asking them to make predictions, asking guided questions, and by clarifying or predicting what will happen next.

The teacher can manage certain features of the units for both the class and individual students. Once a class is set up the teacher can go to the UDL Portal-Info page and click on the "View a report on this class" icon. At the top of the report page there are two options, one that allows you to configure the parameters for students. This allows you to control the font size and set the initial scaffolding level for students. The option on the class report page allows you to enable/disable activities within the units.

The default setting for lesson order when setting up your classes will be a sequenced order of lessons. When students enter the menu page they will complete the Pre-test. When they have submitted the Pre-test they will be able to access the next lesson in the sequence. If you want to allow students to choose their own sequence you can set up your class so that once they have completed the Pre-test and Introduction they can move between lessons in whatever order they like. (A more detailed explanation can be found at http://udl.concord.org/share/teacher-guides/Dashboard.pdf)

Scaffolding in UDL Units

Scaffolding in education has traditionally been done by the teacher as a way to assist students as they are learning new skills or content. The scaffolding is done not to provide answers or do the work for them but as a way for the students to gain confidence and develop understanding of skills and concepts. The goal of scaffolding is that over time the level of assistance that a student needs will gradually be reduced until the minimal amount of support is needed and used. To use a cooking analogy: a chef will use a recipe the first few times he makes a dish. After he has made it several times, he may have the recipe out for reference and then after more time, it becomes so natural he no longer needs the recipe.

In the UDL units different levels of support are offered to students when answering questions. As with the cooking analogy, the scaffolding is intended to provide support for those students who need it with the goal that with time they will be able to work with minimal scaffolding. When scaffolding prompts are available they are accessed by clicking on the green question mark icon. Students may answer the open-ended question as presented. Or, if they are unable to do so, they can click on the question mark and access the first level of support. At this level they are given a hint that may lead them to the correct response. If the student is still unable to answer the question, they can click the question mark again for the answer with key words left out and they can fill in the blanks. If they need additional help, they receive a multiple-choice list. The final level of scaffolding offers the student a model response; they are given the answer and asked to provide their own ideas about the response.

Standards/Benchmarks

NSES Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry.
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    - Design and conduct a scientific investigation.
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    - Develop descriptions, explanations, predictions, and models using evidence.
    - Think critically and logically to make the relationships between evidence and explanations.
- Understandings about scientific inquiry.
    - Mathematics is important in all aspects of scientific inquiry.
    - Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.

NSES Content Standard B: Physical Science (K-4)

- Position and Motion of Objects
    - An object's motion can be described by tracing and measuring its position over time.
    - The position and motion of objects can be changed by pushing or pulling. The size of the change is related to the strength of the push or pull.

Benchmarks for Science Literacy—AAAS

- 1B Scientific Inquiry

    - Scientific investigations may take many different forms, including observing what things are like or what is happening somewhere, collecting specimens for analysis, and doing experiments. Investigations can focus on physical, biological, and social questions.
    - Scientists do not pay much attention to claims about something they know about works unless the claims are backed up with evidence that can be confirmed and with logical argument.
- 4F Motion
    - Something that is moving may move steadily or change its direction. The greater the force is, the greater the change in motion will be. The more massive an object is the less effect a given force will have.

Alaska state standards (http://udl.concord.org/share/teacher-guides/TG_Friction-Beginning-AK-Standards.pdf)

California state standards (http://udl.concord.org/share/teacher-guides/TG_Friction-Beginning-CA-Standards.pdf)

Learning Goals

Friction is a sticky force between surfaces that slows things down or keeps them from sliding.

Different materials have more or less friction. The student should be able to list examples from experiments in the activity:

- Rougher surfaces (e.g., sandpaper) have more friction than smoother surfaces (e.g., wood or metal).
- Rubber has lots of friction.
- Waxed paper has less friction.
- Oil and water can reduce friction.

The friction force is a measure of how much two surfaces resist sliding.

There are several ways to measure friction:

- If there is less friction, something will start sliding down a slide at a lower angle.
- If there is less friction, something will get going faster down a slide.
- If there is less friction, something will coast farther when pushed.
- If there is less friction, it will take less force to pull something horizontally.

If there were no friction, things would keep going for ever.

Background Information

Scientific inquiry is a marriage between evidence and reason, careful observation, and use of evidence to support scientific ideas (Atlas for Science Literacy, AAAS, vol.1). Scientific thought changes as new evidence is presented. Friction is one of the commonly identified forces when talking about motion, but is little understood by students at the elementary level. All students have experienced the force of friction, whether on the slide on the playground, the climbing rope in the gym, or the newly waxed floor in the hallway. Friction is the force that causes the motion between two objects to be reduced.

Leonardo Da Vinci (1452-1519) was one of the first scholar-scientists to study friction. In his work on designing and building machines he recognized the impact of friction in the effectiveness of his machines. He identified two kinds of friction, sliding friction and rolling friction. Da Vinci defined two basic laws of friction:

1. The areas in contact have no effect on friction.
2. If the load of an object is doubled, its friction will also be doubled.

Based on his observations of different materials moving, he noted that they moved with different ease. He believed correctly that this was the result of the roughness of different materials. While he never published his ideas, evidence of them is found in his journals.

Later Guillaume Amontons (1663-1705) worked to discover how friction works. He rediscovered the two laws that Da Vinci had discovered and over the course of his career developed other original theories about friction. His ideas focused on the roughness of surfaces. He thought that friction was mostly the result of the work to lift one surface over the roughness of another, or from deforming of the other surface.

Charles August Coulomb (1736-1806) added to the second law of friction the idea that "strength due to friction is proportional to compressive forces, … although for large bodies friction does not follow exactly this law." In his writing Coulomb referred to Amontons' work leading to the second law of friction to be referred to as "Amontons-Coulomb Law."

The study of friction has continued into present times with F. Philip Bowden and David Tabor (1950) giving a physical explanation for the laws of friction. They were able to determine that the true area of contact is a very small percentage of the apparent contact area. There are asperities (microscopic rough areas) on all surfaces even the smoothest of polished glass. These form the contact points for surfaces. As normal force increases, more asperities come into contact. Research today continues focusing on the micro scale to help better understand friction as a force.

There are three broad types of friction: sliding friction, rolling friction, and fluid friction. Sliding friction results when two solid objects are in contact and a force is applied to one object causing it to slide across the other. Sliding friction force resists the motion. Sliding friction is caused by adhesion between materials, the roughness of surfaces, and in soft materials by deforming of the material.

Rolling friction is a resistive force that slows an object that is rolling. For example, a wheel will start rolling if a force is exerted on it; once it is rolling, rolling friction will take over. This is mostly caused by adhesion between surfaces. The causes of rolling friction are much the same as those that cause sliding friction: adhesion of materials, surface roughness, and material deformation.

Fluid friction occurs when a solid object is in contact with a fluid and a force is applied. There will be friction that resists the motion. When a boat is moving through water or a plane is flying through air, the movement of the fluid (water or air) will cause resistance. The causes of fluid friction are disruptive effects from surface roughness and deformities, adhesion between materials, and deformation resistance of the fluid.

Unit Overview

Activity Title	Activity Length	Materials	Overview

Pre-test	20 minutes	▪ computer with Internet access	A short pre-test allows students to preview unit concepts. Prior knowledge can be identified.
Introduction	15 minutes	▪ computer with Internet access	Students begin to explore the question, "What would happen if there were no friction?" Using pictures and words they identify surfaces that are "sticky" and "slippery."
Frictional Adventure	Two-three 30-minute sessions	▪ computer with Internet access ▪ Printout of story (optional) (http://udl.concord.org/share/teacher-guides/Frictional Adventure34_v5.pdf)	Students read "Maria and Eduardo's Wonderful Summer: A Frictional Adventure," which tells the story of their visit to Sticky and Slippery Worlds. At the end of each chapter students write a summary.
Slip Sliding Away	45-60 minutes	▪ cardboard (50 cm x 10 cm) ▪ wood block (10 cm x 20 cm) ▪ sandpaper (10 cm x 20 cm) ▪ cloth (10 cam x 20 cm) ▪ other materials (foam, rubber, etc. 10 cm x 20 cm) ▪ ruler ▪ tape ▪ computer with Internet access	Students investigate how different surfaces allow an object to slip over them. Using a block of wood and a cardboard slide, students test how high the slide has to be raised for the block to begin to slide. They put different materials on the wood block and lift the slide till the wood moves. The height at which the block starts to slide is measured and compared.
Playground Surfaces	30-45 minutes	▪ computer with Internet access	Students explore different materials using a computer model. In the model they change materials on a slide and raise the slide until the person on the slide starts to move. They record the number of "clicks" that the slide is raised for each surface.
Dragging Shoes	Two 40-minute sessions	▪ force senor ▪ shoes with different type soles ▪ 300 ml (12 oz) plastic bottles that fit into shoes ▪ water ▪ waxed paper ▪ sandpaper (8"x10") sheet—optional ▪ computer with	Students investigate how the soles of different shoes affect how much friction they produce. The material and design of the soles is described. Then using a force sensor, different shoes are pulled across a surface and the force required to move them is recorded.

		Internet access	
Push It	30-40 minutes	▪ computer with Internet access	Students explore friction using a computer model. In the model a box is pushed across different surfaces. The movement is graphed by the computer to help students define how the amount of friction changes as the surface changes.
Measuring Friction	Two 30-40-minute sessions	▪ cardboard (10 cm x 50 cm) ▪ shoe or sneaker ▪ aluminum foil (about 20 cm x 20 cm) ▪ ruler ▪ tape ▪ piece of paper (8 ½ X 11 in.) ▪ computer with Internet access	Students practice measurement skills as they continue to investigate friction. They begin by working in groups to build a standardized tool to measure the classroom. After using their measuring tools, students place a shoe on a cardboard slide and measure the height that the slide has to be lifted to make the shoe slide. The data they collect is graphed and analyzed.
Wrapping Up	Ongoing	▪ computer with Internet access	Students can visit and revisit “Wrapping Up” during their completion of the unit activities. In Wrapping Up they have the opportunity to review and clarify their thinking.
Post-test	20 minutes	▪ computer with Internet access	Students complete the post-test, which contains the same set of question as the pre-test, as well as student feedback questions.

Unit Activities

Pre-test


Time: 20 minutes


Materials: computer with Internet access

This unit begins with a short pre-test. The pre-test allows students to share what they already know about the learning goals. Students must complete the pre-test and press “Submit” button before proceeding to any of the activities. The post-test at the end of the unit contains the same set of questions.

Introduction

Time: 15 minutes

Materials: computer with Internet access

The driving question "What if there were no friction?" is introduced. Students are asked to think about things that are slippery and things that are sticky. This unit explores how different surfaces affect how objects move across each other. After completing the introduction, students will read a story and then do a series of hands-on and computer-based simulations. As they work through the unit it is important to come back to the driving question to help students focus on the force called friction. Posting this question in the classroom is one way to help reinforce the question.

Frictional Adventure — *Story*

Maria and Eduardo are on summer vacation and visit Albert who lives in "Sticky World" and Jennifer who lives in "Slippery World."

Time: two or three 30-minute sessions

Standards/Benchmarks:

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Materials: computer with Internet access (or you can print a PDF version)

Student Activity:

Students read a story about Maria and Eduardo. In the story the children visit Jennifer and Albert. Albert lives in Sticky World and Jennifer lives in Slippery World. While visiting them they discover how things are different in Sticky and Slippery Worlds. While reading the story students are asked to summarize what they have read.

Scaffolding is available using the "robot" coaches, which provide prompts to help students understand the story.

Teacher Notes:

Friction is a force that all children have experienced; they may have already developed some ideas about how it works. They may also have developed some misconceptions, such as:

- Friction always hinders motion. Thus, you always want to eliminate friction.
- Friction is the same thing as reaction.
- Friction depends on movement.
- Friction is always associated with energy, especially heat.
- Friction occurs only between solids.
- Friction occurs with liquids but not with gases.
- Friction causes electricity.

Being aware of these misconceptions and listening to student conversations is important in helping to address misconceptions and helping students develop accurate understandings.

Slip Sliding Away *Hands-on (no sensors)*

Discovery Question: How can you measure how slippery things are?

In this activity students measure the amount of friction of different surfaces. Students slide a block of wood down a slide, covering it with different materials.

Time: 45-60 minutes

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Advanced Preparation: This activity requires you to cut various materials for use during the investigation. Using 2 x 4 scraps of lumber, cut in 20 cm lengths, works well.

Materials:

- cardboard (50 cm x 10 cm)
- wood block (10 cm x 20 cm)
- sandpaper (10 cm x 20 cm)
- cloth (10 cam x 20 cm)
- other materials (foam, rubber, foil, etc. 10 cm x 20 cm)
- ruler
- tape
- computer with Internet access

Student Activity:

Engage:
Students are asked to think about the fastest time they have gone down a slide and what made it so fast. They use the drawing tools to draw a playground slide and label the type of material that their slide is made of.

Explore:
By building a simple slide using cardboard, students begin to explore how friction works. Students place the block of wood on the slide and slowly raise the slide until the wood begins to move. They then measure the height of the slide at that point. After recording the measurement, they are asked to collect three different items to place on the bottom of the block. They make predictions about which will be the most sticky and which the least sticky; they record their ideas on a chart (including the wood). They then test the three materials and record the results.

Explain:
Students begin to develop an operational definition about what increases friction (sticky) and what decreases friction (slippery). They do this by answering questions about what they observed and what evidence supports their answers.

Elaborate:
Having begun to define friction students are asked to explain what materials could be used to slow a person down on a slide and what materials would make a person slide faster.

Playground Surfaces — *Computer model*

Discovery Question: What happens when you change the surface of a playground slide?

In this activity students explore what happens to the frictional forces when the surface of an object is changed. This is done using a computer model of a playground slide where four different surfaces are used.


Time: 30-45 minutes


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Materials: computer with Internet access

Student Activity:

Engage:
Students begin by making a prediction about which of the four materials would be most like Sticky World and which would be most like Slippery World. They then place the surfaces in order from most sticky to most slippery.

Explore:
Students first test the slide made of steel. When they find the height that is takes to start movement they record their data. Then they test wood, carpet, and ice, and record the results after each test.

Explain:
Having observed and recorded the data from the tests, students use this information to reorder the surfaces, from stickiest to slipperiest.

Elaborate:
Based on the observations students are asked to think about what surface would prevent a person from sliding and how the model is like the real world.

Discussion:
Lead the whole class in a discussion using the questions below to start the conversation. Allow students time to clarify their ideas and encourage them to explain their thinking.

"Think about a time when you went down a slide. What do you do to make you slide down faster? What do you do make yourself go down slower?"

"If you wanted to make the perfect slide what materials would you use?"

Dragging Shoes ***Hands-on (force sensor)***

Discovery Question: How do shoes help you walk?

Using various shoes from students in their class and force sensors, students begin to quantify the friction values of the soles of different shoes. Students are asked to make careful observations and describe the soles of the shoes, including the material they are made from and the function of the shoes.

Time: two 40-minute sessions

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Advanced Preparation:

Before starting this lesson, collect 10-15 small (about 500 ml or 16 ounce) bottles. Fill these with equal amounts of water to use as masses.

Materials:

- computer
- force sensor and connection cable for computer
- shoes of different types
- 300 ml (12 oz) plastic bottles) filled with water
- waxed paper
- sandpaper (8”X10”)—optional

Student Activity:

Engage:
Students begin by making a list of different types of shoes. Then they are asked to think about whether all shoes have the same amount of stickiness or slipperiness.

Explore:
Students collect several shoes, either from their group or from other students in the class. To help them get ready to use the smart graphs they practice reading and identifying data points on a graph. Students complete a chart to describe the shoes. They then connect the force sensor to their computer to find the mass of each shoe with a 300 ml bottle of water in it. After finding the mass of each shoe students look at the force required to move the shoe across a surface. Placing a bottle of water in one shoe and connecting to the sensor, they pull the shoe across the floor at a steady rate. They repeat this process with several shoes.

Explain:
Having collected data on the force required to move the shoes over the floor, students are asked to analyze the data and decide which shoe is most sticky and which is most slippery.

Elaborate:
Students now use one of the shoes they tested originally and run the investigation again over three different surfaces: the floor, waxed paper, and sandpaper. The friction value is measured for each. Using what they now know, they are asked to think of a sport where slippery shoes would be an advantage and one where sticky shoes would be an advantage.

Discovery Question: Without friction, would an object sliding on an icy lake ever stop?

In this activity students use a computer model to investigate how friction works on a flat surface when an object is pushed. They are asked to compare the movement when the same force is applied to an object.

Time: 30-40 minutes

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Materials: computer with Internet access

Student Activity:

Engage:

Students begin by imagining what would happen if they were on a sled on a frozen lake and someone were to push them. They write about what they think would happen and why.

Explore:
Using the computer model, students run the simulation with a steel surface, graphing the relationship of time over distance. They then run the simulation after switching surfaces to ice, wood, and carpet. Each time students are shown a graph and asked to describe what the graph shows.

Explain:
Students decide which surface has the most friction and which has the least. They are asked to describe the data from the graphs that supports their ideas.

Elaborate:
Having used the data they collected students are given a challenge to use a slider bar to adjust the friction of the surface so that the object being pushed goes exactly 10 meters. Once they have been successful they use the drawing tools to draw and label the line of a graph for a surface with lots of friction and a line for one with no friction.

Discussion:
Lead the whole class in a discussion using the questions below to start the conversation. Allow students time to clarify their ideas and encourage them to explain their thinking.

"When is having too little friction a problem?"
"What do people do create more friction?"

Encourage students to think about situations where they have encountered the lack of friction, why it was dangerous, and what was done to increase the amount of friction.

Measuring Friction — *Math*

Discovery Question: If a series of measurements vary, how do you decide on the best value?

In this activity students explore measurement, using standard and non-standard units of measurement. The focus is using measurement as part of an investigation of friction. Students are also introduced to the average as a measure of central tendency.


Time: two 30-40 minute sessions


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Materials:

- 8 ½ X 11 piece of paper
- tape
- piece of cardboard (50 cm X 10 cm)
- sneaker or other shoe to test
- aluminum foil (about 20 cm X 20 cm)
- meter stick

Student Activity:

Engage:
Working in small groups, students build a measuring tool using a sheet of paper. They use the measuring tool to measure the width of the classroom. Working with the teacher, the measurements of the various groups are collected and compared. Students are asked what might cause differences in the measurements collected.

Explore:
Students now collect the rest of the materials (cardboard, sneaker, foil, and meter stick) and set up their investigation. They will set the shoe at the end of the slide and slowly raise the slide until it begins to move. The height is recorded and the students repeat the tests five times, recording their measurements each time. The measurements are recorded and graphed by the computer. A series of questions are asked about the graph and students are asked to estimate the average value.

Explain:
Students are asked to identify a statement about measurements and explain why their measurements might not all be the same.

Elaborate:
The investigation is now repeated with a piece of foil placed over the bottom of the shoe. Students record their data and use the data from their two investigations to make comparisons and draw conclusions.

Wrapping Up

Time: Ongoing

Note: Students may want to work on the "Wrapping Up" as they are working on the unit. They can come back to this section as frequently as they would like while they complete the unit. If they have been adding to the "Wrapping Up," they should review and refine their thinking before accessing the post-test.

Materials: computer with Internet access

Having completed the investigations in this unit, students review what they have learned about friction and respond to the discovery question for each activity with text, drawings, snapshots, or data they have collected. Students can revisit any activity except the pre-test. When students are ready, they need to input a password to unlock the post-test.

The password is: **friction**

Post-test

Time: 20 minutes

Materials: computer with Internet access

In the post-test, students have an opportunity to rethink their answers to the same set of questions from the pre-test. Once students open the post-test, they will not be able to return to previous activities.

Note: When the students finish the post-test, a box comes up saying they have finished and should tell the teacher. At that moment, their data is *not yet saved*. They must close the unit for the data to be saved. The student cannot just walk away. Students can close the unit by going to the File menu and selecting Exit, or simply clicking the red circle (upper left) to close it.

Additional Resources

Vocabulary

Average: the middle of a set of values. To calculate it, add up the values and divide by how many there are.

Computer model: a program that runs on a computer and imitates the real world in some way.

Estimate: to make a careful guess of the numerical value of something.

Evidence: what you observe or measure to support an idea.

Force: a push or pull that tends to make an object move, stop, or change direction.

Friction: a force that resists the motion of objects.

Newtons: unit of force. A force of one Newton will accelerate a mass of one kilogram at the rate of one meter per second per second.

Predict: to make a careful guess about how something will happen.

Sliding: moving smoothly over a surface.

Surface: the outside of an object or body.