Why do swings swing?
The teacher guide

Whybricks
Giving physical science form

microbric
motivate • create • educate

Contents

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About Whybricks

Whybricks is an education-focused construction system consisting of 2,100 pieces (210 pieces per student). Each Whybricks kit contains everything needed to enable 10 students to work individually.

Each Whybricks kit contains interlocking building blocks, beams, pegs, gears, and other parts. The individual Whybricks pieces are designed with studs and holes which are compatible with any LEGO brick compatible building system.

Why use Whybricks?

The Whybricks kit, along with the supporting lessons, can help students tangibly access topics that can otherwise feel abstract. Whybricks allow students to explore physical science and engineering phenomenon in a hands-on and engaging way. By enabling students to explore topics through physical activity, students engage in kinaesthetic learning, allowing them to experiment with productive trial-and-error and bridge potential gaps between theory and practice.

The Whybricks lessons use the Whybricks kit to help to support or elevate understanding for any type of learner. The Whybricks kit offers a way to bring hands-on learning in as a functional part of each Whybricks lesson plan.

Managing Whybricks in your classroom

Whybricks offers educators flexible teaching options. Both the Whybricks kit and lessons are intentionally versatile to allow teachers the freedom to implement the materials however best suits their classroom's needs.

The components of each Whybricks kit are supplied with the intention of being a 'pool of parts' for the teacher to use as you see fit. The parts can be organised and stored as best suits your classroom and students. Some ideas for managing the Whybricks kits in your classroom include:

- Create individual 210-part student kits for each student.
- Make up packs with just the parts needed for a specific lesson activity or project.
- Make 'STEM boxes' with instructions and pieces for a challenge for rotation stations.

- Divide up the full kit, arranged by part type, into a storage tray-style storage system, allowing students to find and use the parts they need.
- Provide only a selection of parts in a mixed pack for semi-open and open-ended projects, limiting students from being overwhelmed or distracted by other parts and providing an engineering constraint.
- Keep all the parts mixed together in a single pile free-for-all.

About the 'But, Why?' lessons

This lesson is a *But, Why?* Whybricks Lesson. What does that mean?

Try this.

Ask 10 students the question 'why do people use wheelbarrows?' You will likely end up with 10 versions of the answer 'because it makes it easier.' And they are right, of course!

Your students already know a lot about how the world works. They know that when they let something go, it falls down. They know that riding a bicycle is faster than walking. What they might not know, or may not be able to articulate, is why these things are true.

Now imagine the conversation again:

> You: Why do people use wheelbarrows?
>
> Student: It makes it easier.
>
> You: It makes what easier?
>
> Student: … Doing… the work. You know, carrying heavy stuff, or big stuff.
>
> You: But why?

These lessons will help you flip the script

The *But, Why?* Whybricks Lessons are designed to help teachers transfer agency over learning to students. These lessons help you take your students on a learning journey by asking them 'why?' and supporting them in discovering and presenting their answers using sound engineering and scientific practices.

These Whybricks investigations start by getting students to communicate what they already know about observable phenomenon. By asking students 'why?' up front, the Whybricks investigations help educators determine and celebrate what students already understand. This intuitive understanding is then built upon inside the investigation. Each lesson supports students in growing their grasp of the reasons that underpin the 'why' of what they have already discovered.

The *But, Why?* investigations help students invest in their learning through active and hands-on sciencing (because science is a verb now!) and engineering. The 'why' question format drives the inquiry nature of each investigation, exploring different aspects of physical science and engineering.

Pedagogy approach

The pedagogy behind the *But, Why?* Whybricks lessons set is to deliver physical science education holistically. Through the investigations, students will:

- encounter facts (for example, Newton's second law is mathematically expressed as F=ma),
- exercise a scientific mindset (for example, making observations by answering 'what do you notice?' and developing questions by considering 'what do you wonder?'),
- participate in scientific and engineering practices (for example, by planning and carrying out an experiment or by developing and iterating a design), and
- make real-world connections between the world around them and the material they are learning.

The methodologies used in the investigations are inspired and informed by:

- The PQRST approach developed by DaNel Hogan and Brooke Meyer https://stemazing.org/pqrst/
- The inquiry in the classroom approach as codified by Trevor Mackenzie https://www.trevormackenzie.com/

With great appreciation and heart-felt thanks for your collaboration for constructive disruption.

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The *But, Why?* Whybricks Lesson Set is comprised of the student materials (including the *But, Why?* lesson activity Whysheets, Notice and Wonder sheets and WOW sheets) and the teacher guides. The collection is licensed under a Creative Commons Attribution-ShareAlike 4.0 International (CC BY-SA 4.0)[1].

Using the guides and the lessons

Each *But, Why?* Whybricks investigation is slightly different. As every investigation explores different physical science and engineering topics, the layout, and activities of each one differs to best enable meaningful learning to be achieved. There is no set order in which the investigations should be explored and no wrong way of adjusting an investigation to suit your students or curriculum.

This guide offers support for educators to get the most out of this lesson.

Overview of the student materials

Each *But, Why?* Whybricks investigation is intended to be student-centred and led. With the exception of the teacher guides, the educational materials are all 'student materials' and are designed for independent use by students.

The student materials for this lesson can be downloaded from https://whybricks.com/lesson-set/but-why/

There are three types of interrelated printable student materials:

- Whysheets
- Notice and Wonder sheets
- WOW sheets

An overview of each type of document follows.

About the Whysheets

The core of each *But, Why?* Whybricks investigation is its Whysheet. Much more than a worksheet, a Whysheet is the students' (and educators') guide for the investigation.

[1] Creative Commons licence information can be viewed at http://creativecommons.org/licenses/by-sa/4.0/

Every Whysheet starts with the 'why' question the investigation is centred around. Students answer the question to the best of their ability, drawing on what they already know. The goal isn't to get it 'right' but to codify what they already understand and, over time, get them to think about what they don't understand as well.

The Whysheet will then walk the students through the investigation step-by-step.

Any WOW sheets related to the investigation will be referenced in the Whysheet as will suggestions for when to use the Notice and Wonder sheets. If there is a set Whybricks build, step-by-step build instructions will also be included as an appendix to the Whysheet. You can also encourage students to improve on the set builds, further exploring and applying aspects of physical science and engineering.

The Whysheets, along with the Notice and Wonder sheets, are designed to capture learning evidence as it happens during the investigation, rather than be a 'now that you have finished everything, write in the correct answer' style worksheet. Encouraging students to view the Whysheet as their tool to help them through the investigation will help them take ownership over their learning.

About the Notice and Wonder sheets

The Notice and Wonder sheets are templates designed to work alongside any *But, Why?* investigation. These sheets offer places for students to note observations 'I notice ...' and capture questions 'I wonder ...' throughout the investigation. The Whysheets will indicate key opportunities in an investigation when students will benefit from making notes in a Notice or Wonder sheet, but students should feel free to use these sheets throughout their learning journey, especially for capturing new questions they begin to wonder about as they progress.

Along with the Whysheet, the Notice and Wonder sheets form an important part of capturing learning evidence and empowering student agency in each investigation. All of the Notice and Wonder sheets serve the same purpose, but different versions are available to offer educators flexibility in adapting these to their students' needs.

The Notice and Wonder sheet set includes an educator's overview and recommendation section with additional information.

About the WOW sheets

The WOW in the WOW sheets stand for 'Why? Oh, Whoa!'.

WOW sheets are a way of inserting teaching into an investigation flexibly. For example, you might choose to provide copies of the WOW sheets for students to read in-depth or just reference to find the answers they need. You can also replace WOW sheets with your own lecture or other fact-delivery method on the topic, explaining and exploring as deeply as you see fit.

These sheets are basically reference cards. Each WOW sheet contains information about a specific topic or fact. The WOW sheets help students to discover and understand key information, enabling them to apply what they learn back into the investigation. Examples of the content covered in WOW sheets includes definitions of terms (e.g. 'What is mass?'), explanations of facts (e.g. Newton's third law) and formulas in context (e.g. calculating acceleration, part of the 'What is acceleration?' WOW sheet).

WOW sheets can be used in several ways. You can use them to help guide class-wide explanation sessions or allow students to access them independently when and if they need the information. The WOW sheets can introduce concepts, serve as quick 'refresher' reference cards, or be used retrospectively to demonstrate broader applications of elements encountered inside an investigation.

The Whysheets will indicate key moments in an investigation when students may benefit from using a specific WOW sheet. You may also find it helpful to have the WOW sheets available for students to access at any time.

Overview of the teacher guide

This teacher guide offers overview information plus per-investigation support for educators to get the most out of each lesson.

Remember that the *But, Why?* lesson set is intentionally flexible. There is no set order in which the investigations should be explored. Likewise, while the teacher notes offer additional support for educators, by design they are not overly prescriptive.

The *But, Why?* investigations aim to inspire students to 'think like a scientist' or 'think like an engineer'. Rather than simply explaining how something works, the lessons encourage active participation in learning by conducting experiments and problem-solving. Armed with these experiences, the students are the ones doing the sense-making.

As you might expect, trial-and-error is an inherent part of this approach. To get the most out of their Whybricks lesson, you should support your students as they work through productive struggles without jumping in and 'saving them' from these exciting learning opportunities. Give students a chance to impress you, and themselves, with the thinking they can do. However, you know your students best! Always feel free to adjust any investigation to suit your students or curriculum as you see fit.

For each *But, Why?* investigation you will find teacher notes specific to the investigation that include:

- An overview of the investigation
- A list of the topics covered
- A list of the WOW sheets needed (both those explicitly noted in the student Whysheet plus any additional recommendations)
- Recommendations for running the investigation
- Additional notes specific to the investigation (including sample answers to specific Whysheet questions)

Love these lessons? Hate them? Have an idea for a lesson activity?

The team behind Whybricks would love to hear from you! You can share your feedback and ideas with us through the contact form on our website at https://whybricks.com/support/contact-us/

Why do swings swing?

Overview

This investigation is all about scientific inquiry, getting students to plan and carry out investigations exploring levers, potential and kinetic energy, and Newton's second law (**F**=*ma*). Students take true agency over their learning as they design and conduct an experiment of their choosing to investigate an area related to the core 'why' phenomenon.

Having students plan and carry out their own investigations is one of the best ways to help them to develop scientific mindsets and participate in true scientific practices. It's not without its challenges, of course. Teachers may find the Bozeman Science video *Planning and Carrying Out Investigations* (https://www.youtube.com/watch?v=gP--SQYiagc) helpful in preparing to run this investigation.

Topics covered

- Levers
- Potential and kinetic energy
- Newton's second law
- Scientific inquiry

WOW sheets

Explicitly noted	Also recommended
• Levers • Potential and kinetic energy • Newton's second law	• What is force? • What is mass? • What is acceleration? • What is gravity? • What is weight? • Mechanical advantage • Friction

Additional equipment

- Additional objects of different masses, roughly the same size as the test cube, for the swinging hammer to hit (e.g. erasers, marshmallows, fidget cubes, small weights, etc)
- Tools for measuring distance – rulers, measuring tapes, meter sticks, etc.
- Tools for measuring angles – protractors, etc.
- Tools for measuring mass – digital scales, etc.

Delivery recommendations

The Why question

Before you begin the investigation, have students think about and answer the 'why' question. Offering everyone quiet independent thinking time to start is a good way to ensure all students have the chance to consider what they already know.

You can then have students share with a partner, a group, or the class if you like. If students start to raise questions, encourage them to capture them on a Wonder sheet.

Part 1

The first part of this investigation introduces levers in action and begins to set the framework of energy transfer between objects. Students build the test cube which they will use throughout the investigation. They then build the hammer head and predict what will happen when they use it to move the test cube. After testing and noting observations, students then attach the hammer's handle and repeat the process.

Students then explore what levers are and how the hammer is a third-class lever. They note what they observed about the effects the leverage of the handle had on their ability to move the test cube.

Part 2

The second part of this investigation introduces students to their final experimental apparatus, the hammer stand. Students build the swinging hammer, then tinker and experiment to see how it works.

Building on their understanding of load, effort and fulcrums, students are then introduced to the input force in the swinging hammer: gravitational potential and kinetic energy. After exploring what potential and kinetic energy are, students connect this understanding back to their swinging hammer.

The final element of this section of the investigation looks at Newton's second law (F=ma), laying the groundwork for students to create testable questions related to the swinging hammer in terms of input and output forces.

Part 3

Comprising the bulk of the investigation, part three walks students through the process of designing and then running their own experiment. It's important to note that there is no 'correct' experiment students should arrive at. As long as students can design, run, measure, and report on it, then the testable question they choose related to the core phenomenon is acceptable!

Step 1: Available equipment

For students to be able to design a testable question, they need to understand the scope of what is testable given the materials available to them.

Show students all the materials and equipment available for them to use in their experiment. This should include the tools for measuring dependent variables as well as materials for testing independent variables. Explain that students don't have to use everything available – in fact, they won't be able to use everything because they will only end up choosing one independent variable to test and one dependant variable to measure. Showing the materials and allowing students to tinker and play with the materials and equipment they have access to for their experiment will help students begin to formulate ideas and questions.

The key limiting factor of what will be testable and measurable is the materials and equipment available to students. The more you make available, the wider the range of testable questions there will be. For example, if you also offer materials for changing friction (such as different materials to lay on the flat surface, etc.) students might choose to investigate the relationship between the friction of the surface and the horizontal distance the test object travels.

If you have specific learning objectives you are aiming for, ensure your materials will allow students to investigate those areas. It will also limit their ideas to the concepts you are trying to target.

In addition to the materials you supply, students may brainstorm other materials and equipment they would like to use. It is up to you to allow this or not. So long as the materials students want to use are available, safe, and related to the core phenomenon, allowing this flexibility is a great way to offer agency and student choice.

Once students have had time to explore the materials and equipment first-hand to learn how everything works, they should note observations and questions.

Step 2: Determine variables

Remind students that the goal is to design and run an experiment to discover more about one of the factors they think affects the movement of a swing (in this case, the swinging hammer) or an object hit by a swing (such as the test cube). As such, their experiment is constrained to the Whybricks swinging hammer on its stand and whatever objects you provide for the hammer head to collide with on a flat surface.

With this in mind, students can then brainstorm independent and dependent variables.

A note about variables:

Identifying and categorising variables can be initially challenging if students do not have much experience. This step can be run as a class if that suits your students best. Here are some tips you can use to help work with your students on this step.

- A variable is anything that can change or be changed. In other words, it is any factor that can be manipulated, controlled for, or measured in an experiment. It can be practically anything including components of objects, amounts of time, or events.
- There are two key variables in every experiment: the independent variable and the dependent variable. An easy way to think about independent and dependent variables in an experiment is:
    - the **independent variable** is what you change, and
    - the **dependent variable** is what changes because of that.
    - You can also think of the independent variable as the cause and the dependent variable as the effect.

Examples you might expect students to come up with in this experiment:

- **Independent variables:**
    - Mass of test object
    - Mass of hammer
    - Colour of hammer
    - Material of the flat surface beneath the test object
    - Material of the hammer
    - Height of the hammer at the point of release
    - Length of the hammer's handle
- **Dependent variables:**
    - Distance test object travels
    - Speed of the test object after it is hit
    - Time it takes the test object to stop
    - Speed of the hammer's swing
    - Number of oscillations the hammer makes

NB—not all the independent and dependent variables identified may be testable given your setup. For example, if the hammer is made out of Whybricks, you probably don't have an easy way of changing the colour of the hammer consistently. Likewise, measuring the speed of the test object or the hammer as the dependent variable is probably not likely with the available equipment.

A note about the test objects:

The mass of the swing is a likely independent variable which students will identify. However, changing the mass of the hammer consistently without compromising the functionality of the swing may prove challenging.

Because energy can be transferred from one object to another, the test object is a good stand-in to see the effects of mass in the experiment setup. You may want to point this out to students if they are struggling to see the connection.

Step 3: Determine your question

Once students have brainstormed all the independent and dependent variables available to them to test, they can come up with a testable question. Students should select one independent variable they want to systematically change during their experiment and one dependent variable they can measure.

Step 4: Hypotheses

There's a pervasive habit in cookie-cutter science projects that you choose ONE hypothesis and then see if that is correct or not. Having students fill in all the hypotheses that are possible for the variables they have selected for testing is an important part of cultivating scientific curiosity and breaking habits of biasing results. There's no need for students to 'bet on' which of these hypotheses they think will be correct – they will learn the answer through their analysis of the data from their experiment.

Step 5: Designing the experiment

There are three parts to this step the students need to complete:

- Draw and label a diagram of how they are going to set the experiment up.
- Write out a list of the materials and equipment they will be using for their experiment. ***N.B.*** This is only what they are using in their experiment, not a list of everything they have access to use.
- Write a detailed experiment procedure. There should be sufficient detail so that you, as the instructor, could read it and carry out the experiment exactly the way they are imagining it going. A good rule of thumb is that if a reader needs to ask any clarifying questions ('What does this mean?' or 'How far exactly is the hammer pulled back?') then the procedure is too vague.

The experimental procedure is also where every single variable listed in the 'independent variables' list the student created in step 2 needs to be given a set or controlled value. Alternatively, you can have students add the control settings or values for each controlled variable into the list they made in step 2. In either case, it's important that students understand that the only variable that should be changing is the independent variable they picked to test.

Step 6: Run your experiment and record your data

In this step, students run their experiments, recording the results as they go.

The first thing students need to do is set up their data table correctly. Both the independent and dependent variables should be added and the unit of measure for each one included in the label. By including the units into the column headings, students don't need to include the units in with every number in the table as it is implied that all the measurements in that column take the units in the column header.

Help students identify the best unit of measure to use for each variable and to use it consistently throughout their experiment.

If students are using a test object, remind them to make sure that they place the test object in the exact same spot each time they hit the object with the hammer. Unless the object's location is the independent variable they are testing, the location of the test object should be a control in the experiment.

A note about trials and data:

It is best to have at least five trials or data points at each setting. However, this can be reduced if there is a crunch for time. The results of the trials should be averaged, and this value recorded in the final column.

You can also take the analysis of the data further. Some ideas include:

- Go beyond 'data averages' and have students calculate standard deviation and standard error for their data. This enables students to communicate more with their data, including using more robust evidence to support their claims. Teachers may find the STEMAZing lesson *Beyond Average – Standard Deviation and Standard Error* (https://stemazing.org/beyond-average-standard-deviation-and-standard-error/) helpful in preparing to use standard deviation and standard error.
- Have students create and label a graph using the data from their data table. This can help students to make sense of the raw data, including identifying patterns. They can also use this graph to help present their results.

- Have students write out observations about their raw data (and any visual representations of the data, like a graph). This can help students to think critically about their data and question what they see, including any potential outliers in the data.

Step 7: Present your results

The final step to the experiment is to present the results using the CER (claim, evidence, and reasoning) method. Students answer their original question using one of the hypotheses from step four or a new claim they had not previously considered.

Students then provide evidence that supports their claim by citing data from their experiment. Finally, students explain their reasoning by connecting the evidence to their claim using scientific principles and rules. Questions that can help students with their reasoning include:

- What is the science which caused this to happen?
- What formulas or scientific laws explain why this happened?
- What is the reason behind the behaviour observed in the experiment?

Additional notes

Build notes

There are technically four set builds in this investigation: the test object, the hammer head, the hammer, and the swinging hammer. The hammer head evolves into the hammer which is then used with the stand to become the swinging hammer.

The swinging hammer

- If the bushings on the outside of the axle on the top of the stand are pressed in very snuggly, students may find that the hammer doesn't pivot well but sticks instead. Loosening the bushings will resolve this issue.

Answer key

The sample answers provided are intended to offer guidance only. Student answers will vary depending on their experiences. Answers to the initial 'why' question, the predictions, and the list of ideas are not supplied as there is no 'right' answer for these – they are intended to capture student's initial understanding.

Question	Sample answer
Better tool for moving the test cube	**NB—**This is an opinion-based question. Either choice (the hammer head or the hammer) is acceptable but

	students should include reasoning to support their answer. *Sample answer: hammer head* The hammer head is the better tool for moving the test cube because it's easy to control. The hammer is awkward to use. *Sample answer: hammer* The hammer is the better tool for moving the test cube because it is a lever. I could get the test cube to slide a long way with just a little turn of my wrist.
Effort in the swinging hammer	In a lever, a pushing or pulling input force (called the effort) causes the lever to pivot at the fulcrum. In the swinging hammer, this effort is provided by gravitational potential energy transforming into kinetic energy. When I pull back the hammer, my kinetic energy transforms into gravitational potential energy in the hammer because of the position I put the hammer into. When I let go, the gravitational potential energy transforms into kinetic energy, and the hammer swings.

Outside resources

The resources can serve as great wrap-ups to this investigation and 'provocateurs' to get students thinking about new questions. As links can disappear over time, a description of the content is included so that you can find a replacement if needed. An example 'I wonder…' question is also provided.

1. **The mathematics of a lever** https://www.youtube.com/watch?v=YlYEi0PgG1g
    - **About the video:** This animated TedEx video explores the maths in levers, with an emphasis on first-class levers.
    - **I wonder** what is the longest lever in the world?
2. **The maths of gravitational potential and kinetic energy** https://www.youtube.com/watch?v=MYwqb8m0jkM
    - **About the video:** Illustrated with doodles, this video looks at gravitational energy in the real world, including the maths needed to calculate it, both in its potential and kinetic forms.

- **I wonder** how many Joules of energy the Whybricks swinging hammer has?

3. **Types of potential and kinetic energy** https://www.saveonenergy.com/learning-center/kinetic-potential-energy/#slides
   - **About the resource:** This animated slide deck explores what potential and kinetic energy are, including some of the many forms of energy in the world (including chemical, nuclear, mechanical, and more).
   - **I wonder** if there are any other types of potential or kinetic energy?
4. **The world's biggest swing** https://www.youtube.com/watch?v=amGZySTn_K8
   - **About the video:** This video shows two people take a ride on the world's biggest swing, the Nevis Swing, located in New Zealand. With a 300-metre arc and a 120-metre drop, watch what the power of huge gravitational potential energy can turn into!
   - **I wonder** how fast you swing on that swing?