Why don't you float away when you jump? 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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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.

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 don't you float away when you jump?

Overview

This project's core concept is gravity[2]. While gravity feels intuitively obvious at a basic level, the topic of gravity is one of the most complex studied by physics. Students begin their exploration at the foundational level of understanding gravity as the force that 'makes things fall down'. They then explore the idea of gravitational acceleration and demonstrate that everything on Earth is subject to the same rate of gravitational acceleration (meaning all objects, regardless of mass, fall at the same rate). This phenomenon, coupled with Newton's second law ($\mathbf{F}=ma$), is used to explore what weight is and why mass matters. Air resistance is then introduced as another factor that affects how objects fall on earth. Students then work through the engineering design process as they iterate and test a design that utilises air resistance to slow a falling object.

Topics covered

- Gravity
- Gravitational acceleration
- Weight
- Air resistance
- Engineering design

WOW sheets

Explicitly noted	Also recommended
• What is gravity? • What is weight? • What is air resistance?	• Newton's second law • What is force? • What is mass? • What is acceleration? • Newton's third law • What is friction?

Additional equipment

- Additional Whybricks and other building materials for step 3
  - Student designs will determine the supplies required.
  - Alternatively, you can decide on the available supplies in advance. Show students the available building materials and explain that these are the

[2] This project sticks to Newton's Law of Universal Gravitation and defines gravity as a 'special force'. Segues into Einstein's General Theory of Relativity and gravity are possible if appropriate to your class.

only options for use in their designs. This is an excellent way of introducing the idea of constraints into the engineering design process.

- Materials to track the rate of descent for step 3
    - Ideas include timers and measuring sticks (or other means of marking falling distance). Using a video camera to film the objects falling can also help students review performance and iterate on their designs.
    - Slowing the rate of descent compared to the original design is the most likely parameter students will conceive to mark the improvement of their design against. However, if students come up with a different option that's also appropriate, that's fine! You will probably need to work with the students to see what materials they need to measure their tests.

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.

Student's may write down 'gravity' but not initially offer a definition of what gravity is. Encourage them to explain gravity in their own words. There are a lot of misconceptions about what gravity actually is, so helping students articulate what they think gravity is at the beginning can help open them up to exploring the topic.

Part 1

The first part of this investigation has students explore gravity from a position of familiarity. Using a 24-tooth gear, students run two simple tests noting predictions about how the gear will move when (1) dropped and (2) tossed gently up. These tests support the idea that there is a force (gravity) that 'makes things fall down'. Students then investigate gravity, learning how and why gravitational acceleration on Earth causing things to 'fall down'.

Part 2

The second section of the investigation focuses on things that fall on Earth all the time: types of precipitation. Students use the 24-tooth gear to represent a 'snowflake' and a simple box to represent a 'hailstone'. Students predict[3] which object will fall the

[3] To get the most out of this test, ensure that students make their predictions before they run the test. You may want to run this section as a class, reading the test explanations together and getting students

fastest (i.e. hit the ground first) and then run the test to discover that this is a trick question: the objects hit at the same time[4]!

Students then experiment with their hailstone and snowflake to see how Newton's second law of motion explains that while the objects fall with the same rate of acceleration, the force with which they impact the ground is different[5]. The concept of weight as the force of gravity exerted on an object is investigated. Students use this idea to explain why a hailstone can cause damage to a car but a snowflake doesn't.

The idea that other forces can influence how things fall is then introduced and the topic of air resistance is investigated. Students tackle the question of 'why can a hailstone damage a car while a snowflake doesn't?' again, this time also considering the role of air resistance.

Part 3

The final section of the investigation invites students to apply what they've learnt about gravity and air resistance to an engineering design challenge. The goal of the challenge is to use air resistance to get their hailstone to fall more slowly.

This section is laid out in three steps:

1. Brainstorm
2. Test design
3. Iteration (i.e. 'Build, test, learn, repeat')

When it comes to 'engineering', there's a temptation to jump straight into building. However, engineers are problem solvers first and foremost. Understanding what the goal is, what constraints there are and how success will be measured are important parts of the engineering design process. The three steps of part three of this

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to write down their predictions to prevent them from jumping straight into the test. Likewise, running this as a class will allow you to control the objects' drop, ensuring that height and timing is aligned.

[4] The snowflake and hailstone should absolutely fall at the same time. Air resistance is not sufficient against the two objects to impact their rate of acceleration. Be sure the two items are at the exact same height and dropped at the same time. Having students work in partners or groups will let at least one person watch from the ground, confirming the objects hit at the same time. Likewise, you can film the drop and watch it back (even in slow motion) to demonstrate this phenomenon.

[5] The difference in mass between the hailstone and the snowflake should be apparent to students but might be overlooked as a factor. You may want to draw attention to this fact. Using a scale can help, but may cause confusion around the non-physical science understanding of 'weight'. However, that provides an opportunity to explain that a scale actually measures force, but provides the unit of measure as kilograms, grams, etc. (rather than newtons). This can be a bit confusing, but it's because weight and mass are so connected that they are often used interchangeably in everyday life. A side note about pounds: a pound is actually a force! Look up 'pounds, slugs and the British Gravitational system' to learn more!

investigation are designed to help students work through the engineering design process in a painless but meaningful way.

Suggestions on how you can run each step follows, however, feel free to adjust this challenge to suit your class.

Step 1: Brainstorm

Not all students will feel confident about an engineering design challenge. A brainstorming session is a great way to get the creative juices flowing. Tell students that this is just about coming up with ideas, which is all about being imaginative, using their creativity and thinking about possibilities. Whether or not these will work isn't the current concern – there's a whole other step for that!

Depending on your students' confidence with making, you may want to allow the first few rounds to be completely open: allow them to generate ideas by getting their thoughts to flow freely. Let them know that all ideas are acceptable, no matter what they are. Encourage students not to make decisions about whether the ideas are possible or judge the ideas while they are brainstorming.

One way to do this is to run a timed brainstorming session. Set a timer for 45 seconds – that's all the time students have for the first idea before they must move onto the next. Allow students to capture ideas however they like: draw, write down a description or a bit of both. Tell them the main rule is that they are not allowed to NOT come up with ideas. Remind them that there are no 'bad' ideas during a brainstorming session! As soon as the timer goes off, reset it and have students move on to the next idea.

After a few rounds, pause. Introduce the materials students will have available to them to use in the engineering challenge. Then start the brainstorming session up again, this time encouraging students to think about possibilities using the available materials. You can keep the timer set to 45 seconds or increase it slightly as you see fit.

Once you have finished brainstorming, give students a few minutes to analyse the ideas they came up with. Looking at all of their ideas together can help students evaluate their ideas, choosing which ones they feel are better than others. This can help students in selecting one idea to use as a starting place in designing their creation.

If you are going to have students work on the rest of the design challenge in pairs or groups, the wrap-up of the brainstorming session is also a good time to get the groups together. Sharing ideas and discussing their thoughts at this stage will help students in the next step as they design their test.

Step 2: Designing the test

There's no way to know whether or not a design is successful without criteria and a test. That's what step two is all about. This step is often overlooked in engineering projects, but is critically important.

A key parameter of the test is established in the goal for this design challenge on the Whysheet (get the engineered hailstone to fall more slowly than the original hailstone). This is an important clue about the major thing students need to know in order to run their tests: the rate of descent of the original hailstone (or some equivalent way of comparing their design to that of the original hailstone).

Most students will find that the test they devise to determine the rate of descent for the original hailstone will be a good test for their engineered solutions as well. It's important that they note the procedure and how they measure carefully so this can be repeated for their own designs as well.

Depending on your students, you may choose to guide your class through this step. In helping students create the test, note the dependent and independent variables, materials and equipment that will be used and the experimental procedure. The experimental procedure should be detailed enough to allow data collection and to be able to be repeated exactly as described.

Like all things in engineering, students may encounter issues while designing the test. Allowing for some trial and error while students determine the rate of descent of the original hailstone will help iron out issues with their tests. This will make testing their iterative builds much smoother in the next step.

A note about testing:

It's generally considered good practice to run five (5) trials of a test and then average the results together. Given the quick rate of descent of the original hailstone, this approach is an option worth considering.

A note about height:

The original hailstone falls very quickly. If you can provide a safe drop point for students to use that is at least a few meters above the ground, students may find it easier to measure the rate of descent and to utilise air resistance. However, the higher you go, the more likely builds will break apart on impact, so do keep this in mind when selecting your drop point!

Step 3: Iteration

This step is where students get into the heart of the engineering design process as they build, test, learn and repeat.

Depending on the materials available to them for use in their designs and the tests that students have created, this step can vary widely even in a single class. Some students' initial iteration may be quite solid and their further iterations are mainly refinements. (Remind students also that they can 'take a step back' to a previous iteration, undoing something they tried to go back to a better result and then iterate from that point.) Other students may decide to switch tactics completely after one or two attempts. Still others may try completely different ideas with each iteration to see what works. These are all valid approaches. If you are looking for students to approach this step in a particular way, offer guidance as students proceed to direct the learning outcomes you are seeking to achieve. Otherwise, allow students the freedom to tinker, experiment, fail and learn!

A wrap-up section completes this step. Students reflect on all of their designs and explain their most successful design, including why it was the most successful.

A note about testing:

It's generally considered good practice to run five (5) trials of a test and then average the results together. If you are using a relatively low drop point or if student builds descend quickly, this approach is strongly recommended as it can help average out timer issues, etc.

A note on printing step 3 of the Whysheet:

Pages 12-21 of the student Whysheets include ample space for the full note capture of five iterations. You do not need to print all of these pages if students capture the relevant information in a notebook or similar system elsewhere. Having the template available for students to refer to is recommended.

Additional notes

Build notes

There is only one set build in this investigation: the hailstone (initially built and used in part 2, then used as the base of student designs in part 3).

The hailstone (base design from part 2)

- The hailstone may fall apart if it hits a very hard surface or lands on a corner of the build. However, the pegs should keep the base together and this should allow for a quick rebuild.
- When students enter part 3, they should use the base hailstone as the core of their design. However, some students may come up with ideas that destroy the 'core' hailstone. Whether or not this is allowed is up to you!

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 and the predictions are not supplied as there is no 'right' answer for these – they are intended to capture student's initial understanding.

Question	Sample answer
Gravity, the 24-tooth gear and Earth	Newton's third law of motion tells us that when object X (in this case, the Earth) exerts a force on object Y (in this case, the gear), then object Y (the gear) exerts an equal and opposite force on object X (the Earth). Newton's second law of motion tells us that same size force will cause an object with greater mass to accelerate less. Because the Earth has so much mass, the acceleration caused on the Earth by the gear traveling up isn't noticeable. But the acceleration that results from the Earth exerting that same size force on the gear overcomes the other forces, eventually making the gear fall to the ground.
Explanation based on weight: hailstone vs. snowflake	A hailstone has more weight than a snowflake and, so, it hits the car 'heavier' (i.e. with more force) than the snowflake. The gravitational acceleration (i.e. the rate at which the objects fall) is the same for both the snowflake and the hailstone, but the hailstone has more mass. Since weight = mass × gravity, the object with more mass is heavier. The heavier object hits the car with much greater force, and this can cause damage.
Explanation based on weight and air resistance: hailstone vs. snowflake	A hailstone has more mass than a snowflake. That means the hailstone has more weight than the snowflake. The gravitational acceleration (i.e. the rate at which the objects fall) is the same for both the

	snowflake and the hailstone. Both also encounter air resistance. But because the hailstone has a decent amount of mass, air resistance isn't a strong enough force to change its acceleration caused by gravity. However, the snowflake has very little mass and has a comparatively large, flat leading edge as it falls. The force of air resistance is enough to change the snowflake's acceleration, slowing it down. Because the hailstone has more mass, air resistance isn't enough to change its acceleration and because it has more weight, it hits the car 'heavier' (i.e. with more force) than the snowflake which is why it can cause damage but a snowflake doesn't.

Outside resources

These 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. **A bowling ball and a feather falling in a vacuum chamber**
   https://www.youtube.com/watch?v=E43-CfukEgs
   - **About the video:** Brian Cox visits NASA's Space Power Facility in Ohio to see what happens when a bowling ball and a feather are dropped at the same time in the world's largest vacuum chamber. By removing air resistance, this chamber replicates the conditions of outer space and demonstrates that gravitational acceleration on Earth is the same on objects of any mass.
     - **N.B.** The end of this video introduces the beginning concept of Einstein's General Theory of Relativity, which is a very different, and considerably more complex, explanation of gravity compared to Newton's Law of Universal Gravitation.
   - **I wonder** what would happen if you dropped the bowling ball and feathers out of the International Space Station?
2. **Gravity explained in 5 levels of depth**
   https://www.youtube.com/watch?v=QcUey-DVYjk

- **About the video:** Astrophysicist Janna Levin, PhD, talks about the concept of gravity with 5 different people; a child, a teen, a college student, a grad student, and an expert.
    - **N.B.** This is a long video that gets into very complex explorations of relativity as it progresses. However, the first section ('a child', ends 5:16) sticks to classic Newton gravity. The second section ('a teen', ends 12:25) offers a comparatively straight-forward introduction to the concept of relativity.
- **I wonder** if I'm taller in the morning than at night?

3. **Hailstones smash a car windshield**
   https://www.youtube.com/watch?v=czywMNifBNE
   - **About the video:** Recorded from inside a car caught in a hailstorm, watch as hailstones hit the windshield causing increasing damage.
   - **I wonder** how big was the biggest hailstone ever recorded?
4. **Less mass means more air resistance (3 round objects)**
   https://www.youtube.com/watch?v=dWZvAFEMIsE
   - **About the video:** Three round objects with different masses: a small soccer ball (fairly heavy, around 200g), a big beach ball (mass around 65g) and a balloon (mass about 7g) are tossed up gently. Air resistance affects the objects based on their mass, resulting in the soccer ball flying smoothly, the beach ball floating a little and the balloon appearing to 'hang' in the air.
   - **I wonder** if you would have the same result with objects that are cube-shaped?