Why don't bridges collapse in the middle? 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 don't bridges collapse in the middle?

Overview

This project investigates two forces that make bridges useful to people: normal force and tension. Students first investigate how normal force allows a bridge to support a load. They then observe the additional challenges involved with making a longer bridge. Students explore how tension is used with upward support beams in bridges to create a strong bridge. An optional extra challenge allows students to test the concept in practice, substituting in string for the sturdier Whybricks parts and observing the results.

Topics covered

- Normal force
- Tension

WOW sheets

Explicitly noted	Also recommended
• What is normal force? • What is tension?	• Newton's second law • Newton's third law • What is force?

Additional equipment

- None
- *Optional extension challenge:* yarn or string

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 the investigation introduces students to balanced forces on a bridge. The running procedure for this part is:

1. Create a simple bridge from instructions

2. Read about a test they will perform using the build[2]
3. Write a prediction about what will happen in the test
4. Run the test
5. Capture observations and questions

At the end of step one, the concept of normal force is formally introduced. Students then explain the concept in their own words using their bridge test as an example.

Part 2

Following the segue at the end of part one, the second part of the investigation focuses on the challenge of creating a bridge that can span across a canyon. The running procedure for this part is:

1. Create the canyon from instructions
2. Create a bigger bridge from instructions
3. Read about a test they will perform using the build[3]
4. Write a prediction about what will happen in the test
    - It is likely that students will quickly observe that the bigger bridge will not be able to support much force. This begs the question of how real-world bridges are designed to be both long and strong. You may choose to have and share some photos of famous bridges, such as the Golden Gate Bridge in California or the Tower Bridge in London.
5. Run the test
6. Capture observations and questions
7. Investigate tension and think up a way that tension could be used in their bridge design
8. Modify their 'bigger bridge' into the 'stronger bridge' from instructions
9. Repeat the bridge strength test

Bonus challenge and wrap-up

The final optional part of the investigation challenges students to replace the four 15-hole long beams which are creating tension in their bridge with string. This is a great mini-engineering challenge that helps 'prove' how tension is at work in the stronger bridge design.

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[2] Ideally, students should 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 to write down their predictions to prevent them from jumping straight into the test.

[3] Ideally, students should 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 to write down their predictions to prevent them from jumping straight into the test.

Once students have completed the final part of the investigation, the Whysheet asks them to reflect on their original answer to the 'why' question and prompts them to capture new questions brought on by what they've discovered in this investigation. They can then break down their builds back into the component parts.

Additional notes

Build notes

There are four builds in this project, the simple bridge (built and used in part 1) and the canyon, the bigger bridge, and the stronger bridge (all built and used in part 2).

The simple bridge (from part 1)

- The student should notice that the bridge flexes slightly when they press firmly in the middle. It doesn't collapse, but that is a sign of the strain it feels from a large load.

The canyon (from part 2)

- This build creates two identical parts that act as the walls of a canyon. Both the bigger bridge and the stronger bridge use the canyon.

The bigger bridge (from part 2)

- This build requires the completed canyon build.
- This bridge is not very sturdy when placed on the canyon. While the bridge can be made to hold flat over a narrow canyon, or if the bushings on the central axle are pushed in very tightly, it will likely collapse when the canyon is sized to be the length of the bridge even under just its own weight.

The stronger bridge (from part 2)

- This build requires both the completed canyon build and the completed bigger bridge build.
- This design builds on from the 'base' of the bigger bridge.
- Students may find it challenging to attach the tension rods to the bridge platform. To achieve this, the beams have to 'bend' slightly to attach to the inside of the vertical supports and the outside of the platform. Once the beams are in place, they are straight.
- This bridge should be strong enough to support a significant amount of weight. You may want to test out just how strong the bridge is with your students. One option is to find a textbook that will fit in between the vertical supports of the bridge and test if the bridge can support the weight. Can additional objects be added?

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
Normal force on the bridge	Normal force is a contact force that objects experience when they touch. The normal force is perpendicular to where the surfaces touch. This is the force that prevents solid objects from passing through each other. An example of normal force happens when I push down on the simple bridge with my finger. I produce a downward force on the bridge and the bridge produces an upward force on my finger, which is the normal force. No matter how hard I pushed, the bridge produced a normal force that was equal to my downward force. That's why my finger never pushed through the bridge.
Tension and the bridge	***NB –*** *this question asks students how they 'think' tension could be used. Their solution does not need to be viable from an engineering point of view, but should demonstrate an understanding of what tension means and include an attempt at applying that to their bridge.* I think that tension could be used to tie the bridge to the canyon. If a big rope or cable was used at each end of the canyon to tie the bridge to the canyon, then the ropes would be under tension. This is because one end of the canyon would pull on each end of the bridge. The whole bridge would then be under tension and won't be able to move.

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. **What makes bridges so strong?**
   https://www.youtube.com/watch?v=oVOnRPefcno

   - **About the video:** Part of the made-for-kids SciShow Kids series, this video investigates three common bridge types (beam, truss and suspension) and looks at what about the designs (including triangles and tension) makes them strong.
   - **I wonder** how engineers choose the type of bridge to build?

2. **Spaghetti bridge design challenge**
   https://thekidshouldseethis.com/post/spaghetti-bridges-engineering-challenge-activities-for-kids

   - **About the video:** Part of the James Dyson foundation challenge series, Mechanical engineer Shini Somara introduces how engineering enables different kinds of bridges to successfully distribute weight of their load throughout their structures.
   - **I wonder** if I could make a strong spaghetti bridge?

3. **Why did the Tacoma Narrows bridge collapse?**
   https://www.youtube.com/watch?v=mXTSnZgrfxM

   - **About the video:** A walk through of one of the most famous case studies of bridge design, the Tacoma Narrows bridge located outside of Seattle, Washington, in the USA, which collapsed during a major wind storm.
   - **I wonder** how new designs are tested for unexpected failures before they are built?

4. **How do engineers build a bridge over water?**
   https://www.youtube.com/watch?v=Yv3RM803bzw

   - **About the video:** Explore some of the most common engineering techniques used when building bridges in and over water.
   - **I wonder** how do engineers decide what techniques to use when building a bridge?