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Drawbridge for AutoSTEM

Construction instructions and pedagogical guidelines

This guide includes the following parts:

- How the Drawbridge can be used to learn STEM content
- How to construct the Drawbridge

How the Drawbridge can be used to learn STEM content

What is the Drawbridge?

The Drawbridge is a toy bridge that can be raised to allow passage of a ship having masts too tall to pass under or to defend the entrance of a medieval castle. It is made from double-wall corrugated cardboard (from a big parcel), a wooden skewer, and string. The toy can be used by the children in many ways and opens up a number of subject areas for further learning. Moving bridges are very motivating and exciting toys for children. It is fun for the children to be allowed to play with their drawbridges, once they have made them.

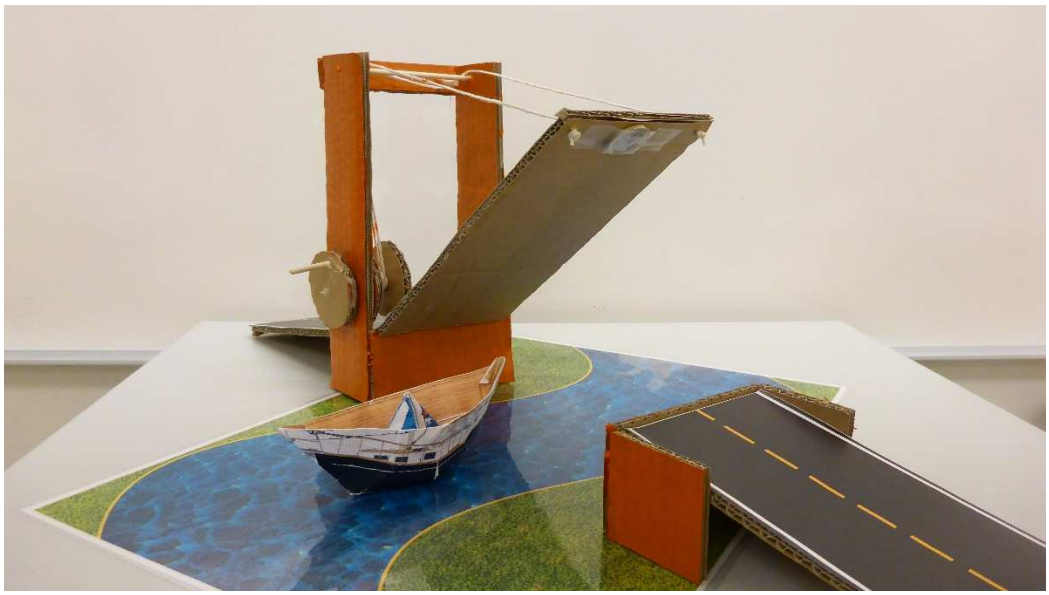

Figure 1. An example of the Drawbridge

Target group

The Drawbridge example described here is designed for children from 5 to 8 years old. Teachers can adapt the proposal to other ages.

The teacher can decide depending on her/his knowledge of the children whether the children should work in groups or individually.

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Learning goals

When constructing the Drawbridge several learning goals can be achieved:

- To learn about physics and mechanisms
- To develop engineering competencies of analysis and construction.
- To learn mathematical concepts within the construction and assembly process, including shapes and numbers.
- To practice measuring
- Other soft-learning goals can be included; problem solving and creativity.

How to introduce STEM concepts during construction

The starting point is the Drawbridge, how it functions, and how to construct it.

Observing

The first thing the teacher does is show a model of the Drawbridge and make it move up and down. The teacher can ask, 'Why did it move?'

Exploring and learning about physics and mechanisms.

Children can observe the Drawbridge, make comments, and ask questions about how it functions.

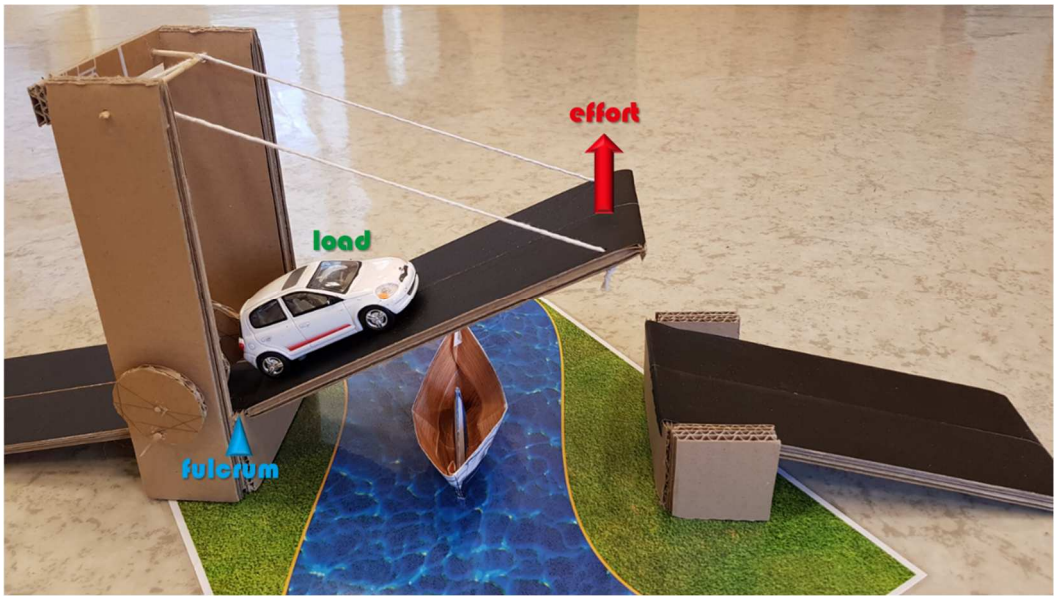

Figure 2. The Drawbridge is a type 2 lever

Our drawbridge is a **type 2 lever**. The **fulcrum** is where the movable deck is attached to the bridge tower. The **force** to raise the deck is applied on the other end. The further away this point is from the fulcrum (i.e. the longer the

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lever arm is), the lesser force is needed to raise the bridge. The **load** is the bridge deck itself or a car that may stand on the bridge while it is raised.

When you apply a force to the handle of the **crank** of the **winch** in order to turn it, you do **work**. This **mechanical energy** is transformed into the **rotational kinetic energy** of the winch spool. The rotational energy is transformed into **translational kinetic energy** of the string. The translational energy is transformed into **gravitational potential energy** of the raised bridge deck.

When releasing the crank, the process would usually reverse. That means the gravitational force would pull the bridge deck down again. But in our model, the **friction** between the winch's **axle** and its **bearing** is so high that it **balance**s the gravitational force (the **weight**) of the bridge deck. Therefore, the raised bridge deck stays in place. In order to lower the bridge, you have to turn the hand crank in the opposite direction.

Starting to construct the Drawbridge and learning mathematics

The teacher talks with the children asking what is needed to make the Drawbridge. During the construction, many mathematical concepts can be used, introduced, or discovered.

- **Counting**: parts **B** and **E** are needed **three times**, parts **A**, **C** and **F twice**, part **D** only **once**
- **Measuring lengths**: The string and the skewer have to be cut in pieces of specific lengths. The lengths can be found by **direct comparison**, measuring with body units (an **arm span**, i.e. the distance, fingertip to fingertip, created by stretching one's arms straight out from the sides of the body) or standard units (**metre** and **centimetre**).
- **Designing (shapes)**: Parts **C** to **E** are **rectangles**, **A** is a **square**, and **B** is a **circle**.
- **Locating**: use spatial concepts like **under**, **over**, **through**, **top**, **bottom**, **centre** (find the centre of a circle), **up**, **down**, **around**, **clockwise**, **counter-clockwise**, **rotation** (the motion of the spool), **translation** (the motion of the string)

Expanding on the idea

The initial bridge idea can lead to further ideas and explorations. The teacher can ask the children for their ideas. Are there other mechanisms of drawbridges? Are there other types of movable bridges? One famous example is the Tower Bridge in London that has two movable spans (fig. 3). Our drawbridge can easily be modified to have two spans by doubling it.

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Figure 3. The Tower Bridge in London (picture taken by Roberto Bellasio, Pixabay)

The drawbridge can be used in a *castle scenario* together with other automata, e.g. a trebuchet, a trapdoor or a hoist.

In a *traffic scenario*, the children can use the drawbridge together with the Balloon boat and the Balloon car. They can extend the road and find a way to make a water channel that the bridge will span.

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How to construct the Drawbridge

To make the Drawbridge you only need basic parts and tools that are found in every school or preschool. Below we list the parts needed and alternatives.

Parts and tools required

- about 40cm x 50cm double-wall corrugated cardboard (taken from a used package)
- a wooden kitchen skewer (If it is a short one, you might need two.)
- string (twine or cord of thread or yarn)
- glue (hot melt glue gun works best)
- sticky tape
- scissors
- a knife or guillotine to cut the cardboard
- a ruler
- (optional) paint

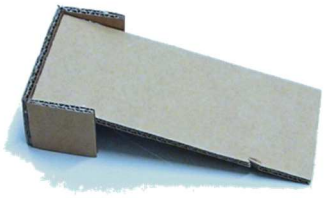

Figure 4. The opposite approach span

Method

It is best to watch the video https://youtu.be/Ah-l88JAAaE.

1. Cut out the templates from page 10 and 11.
2. Use the templates to cut the cardboard. It is best to place the cut out paper on the cardboard, draw around them and then cut out the shapes.
3. Assemble the opposite approach span by glueing together pieces **E**, **C**, and both pieces **A** as shown on fig. 4.
4. Do the same with the bridge tower and the approach span that is connected to it by using pieces **E**, **C**, and both pieces **F**.
5. Glue piece **D** to the bridge tower (fig. 5).
6. Attach the movable bridge span **E** (fig. 6):
   a. Stick a piece of the strong sticky tape on one end of the remaining piece **E**.
   b. Stick it to the top end of the approach span by the bridge tower.

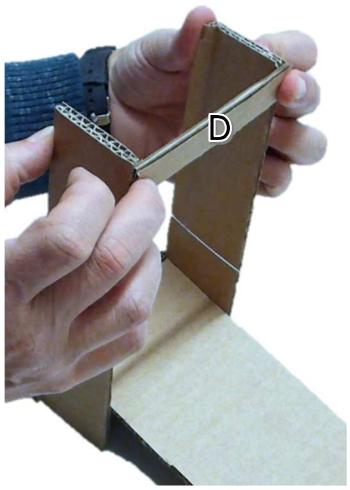

*Figure 5. Glue piece **D** to the tower*

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c. Check that you can easily flap it up and down.

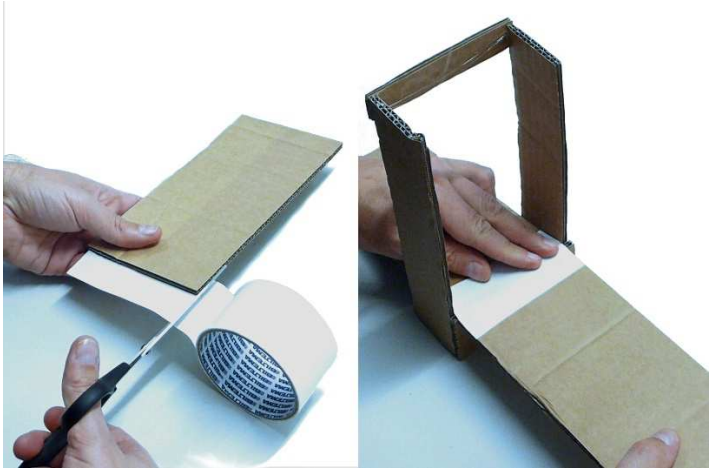

Figure 6. Stick a piece of sticky tape on piece **E** *and attach it to the bridge*

7. Make **pulley 1**:
    a. Use the pointy end of the skewer to prick a hole in either side of the top of the bridge tower. You can use template **F** that shows the position of **hole** ①.
    b. Push the skewer through both holes until the straight end sits in one hole.
    c. Mark on the skewer where it sticks out of the other hole in order to measure the length that is needed.
    d. Pull the skewer out of the holes and cut it at the mark.
    e. Insert it again between the two holes at the top of the tower. This is **pulley 1**.
8. Use the pointy end of the remaining piece of the skewer to prick two holes in piece **D**. You can use template **D** that shows the positions of **hole** ② and ③.
9. Make **pulley 2** and **3**:
    a. Mark on the remaining piece of the skewer the distance from piece **D** to the **pulley 1**.
    b. Cut two pieces of this length from the skewer.
    c. Insert one piece in **hole** ②. It shall go **under pulley 1**. This is the **pulley 2**.
    d. Insert the other piece in **hole** ③. It shall go **over pulley 1**. This is **pulley 3**.

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10. Put the three circles **B** on top of each other and prick a hole in the centre through all three pieces. You might use template **B** that shows the position of **hole** ④ or let the children invent a clever method to find the centre.
11. Push the remaining piece of the skewer through the centre of one circle. Use this to find the position of **hole** ⑤ and prick it into the bridge tower. The hole must be on the same side of the tower as **pulley 3**. It needs to be that high enough that the circle is just above the bridge deck but can still rotate freely.
12. Measure a piece of the string by stretching your arms straight out from the sides of your body from. The string shall be one **arm span** long. Then cut the piece into halves. (Each piece of string will be about 80—90 cm.)
13. Measure a piece of the skewer 5 cm long and cut it off.
14. Insert this piece in one of the circles so that it sticks out on one side only. This is the **spool** of the **winch** with one **flange**.
15. Take a piece of sticky tape (about 1 cm wide and 5 cm long) and stick the ends of the two strings on to it (fig. 7).
16. Then wind the sticky tape together with the strings around the **spindle** of the **spool**, close to the **flange**.
17. Put a second circle on the **spindle** as the other **flange**.
18. Attach the **winch** to the inside of the tower by pushing the **winch**'s **axle** through **hole** ⑤.

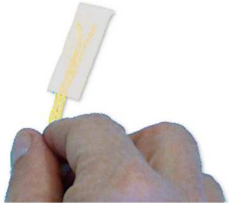

Figure 7. A piece of sticky tape

19. Take the last circle and prick **hole** ⑥ close to the circumference. You can use template **B**.
20. Insert the last piece of the skewer into **hole** ⑥ and attach some glue. This will be the **handle** of the **winch**'s **crank**.
21. Attach some glue to the hole in the centre of the **crank** and attach the **crank** to the free end of the **winch**'s **axle**.
22. Prick two holes in the bridge deck, close to each free corner. You might use template **F** that shows the positions of **hole** ⑦ and ⑧.
23. Turn the **winch** clockwise three full rotations so that the strings coil around the **spool**.

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24. Take the **right-hand** string (the one that is closest to the edge) and pass it **upwards** and **through** the opening between **pulley 1** and **3** and finally **over pulley 1**.
25. Take the other string and pass it **upwards**, too, **through** the opening between **pulley 1** and **3**, to the **left over pulley 3** and **under pulley 2**, then **upwards through** the opening between **pulley 1** and **2** and **over pulley 1** (fig. 8).
26. Turn the bridge around and push either string **through hole** ⑦ and ⑧ without crossing the strings.

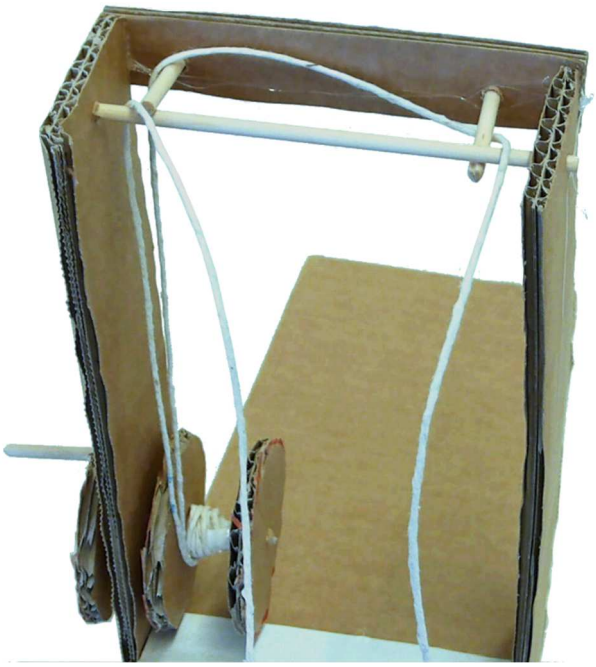

Figure 8. Arrangement of the strings

27. Mark on each string the point where it meets the hole.
28. Move the bridge span **upwards**.
29. Make a knot in each string at the marked point.
30. Cut away the part of each string that is behind the knot.
31. Use your creativity to decorate the bridge. You may print out the road paving (on page 12) three times and glue it on the bridge decks.

Test the bridge and make it move

You raise the bridge by turning the **crank clockwise**. When you turn the **crank counter-clockwise**, the bridge should move **downwards**. If it does not move downwards by itself, you have to increase the weight. You can use sticky tape to attach a coin to the bottom of the bridge deck, or you can use a spring from a ball pen to pull the bridge down (fig. 9).

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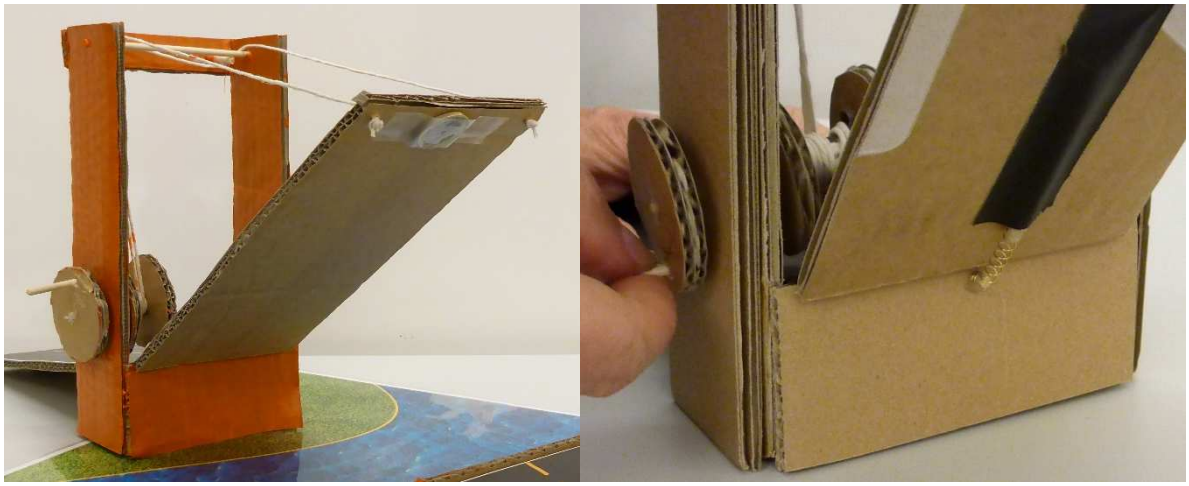

Figure 9. You might use a coin or a spring to pull the bridge down.

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Templates

A **(2x)**

5*cm* **x 5***cm*

B **(3x)**

↖hole ⑥ ↖hole ④

∅ = 5*cm*

C **(2x)**

11*cm* **x 5***cm*

D

11*cm* **x 2***cm*

↖ hole ② hole ③ ↗

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E (3x)

10*cm* **x 22***cm*

↙ hole ⑦

hole ⑧ ↘

hole ① ↗

F (2x)

5*cm* **x 22***cm*

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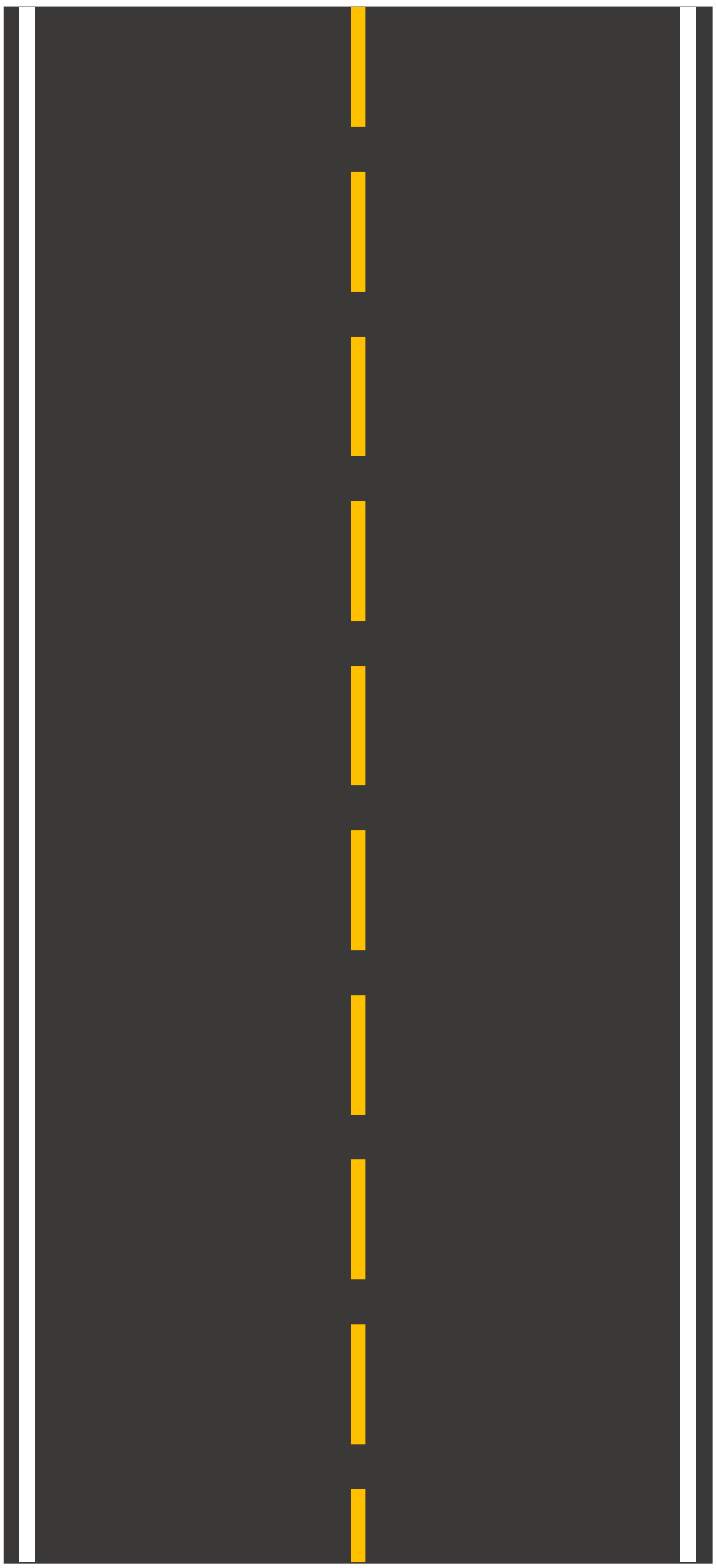

Road paving

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