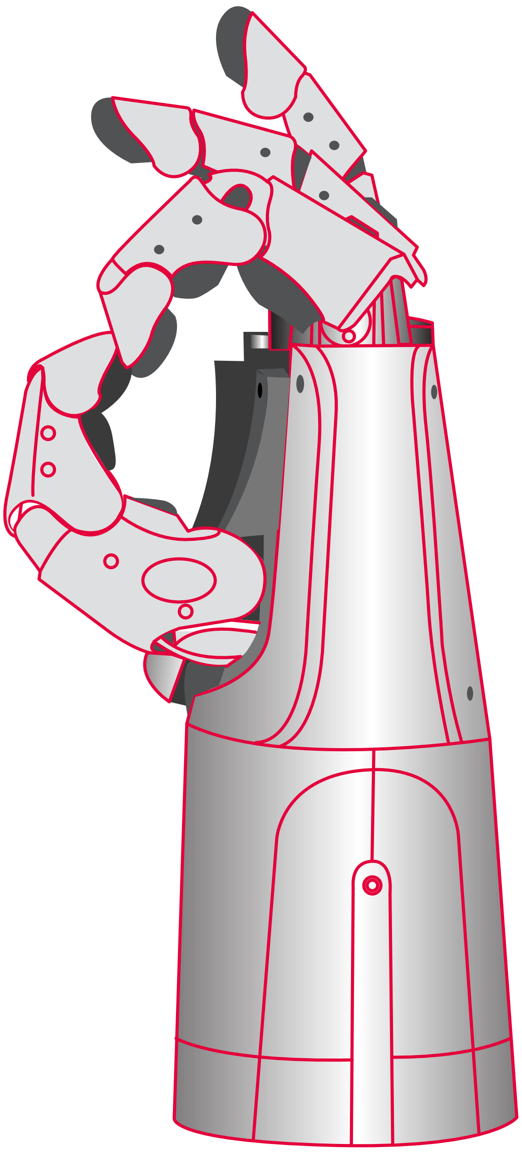
primary | PR34

teach with space

→ BIONIC HAND

Building a bionic hand



teacher guide & student worksheets

European Space Agency

teach with space – bionic hand | PR34
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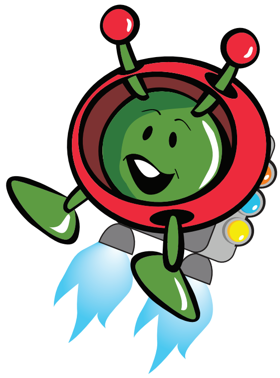


→ BIONIC HAND

Building a bionic hand

Fast facts

Subject: Science, Arts

Age range: 8-12 years old

Type: student activity

Complexity: easy/medium

Lesson time required: 60 to 90 minutes

Cost per class: low (0-10 euros)

Location: classroom

Includes the use of: craft material(cardboard, craft knifes, glue gun)

Keywords: Science, Arts, Moon, Bionics, Robotics, Human Body

Brief description

In this activity, pupils will build a bionic hand made out of cardboard, strings, straws and rubber bands. They will relate the bionic hand to their own hand to understand the function of the fingers and the importance of the thumb, to grab or hold objects with different shapes and forms. Pupils will also learn that it would not be possible to move the human hand if it was only composed of bones. The pupils will understand how bones, muscles, tendons and ligaments work, by comparing them with the materials used on the bionic hand to move the fingers.

This activity is prepared for 60-90 minutes, depending on the age of the pupils. However, this resource can be proposed as part of a classroom project; encompassing other subjects of study such as arts, language, and the human body.

Learning objectives

- Understand how the human hand works.
- Learn that science and medicine use bionic prosthetics to substitute parts of the human body that are not working properly or are missing.
- Learn that scientists use the human body as inspiration to build tools, such as hands and arms in hostile environments like space or the deep ocean.
- Explore and test ideas building a simple machine (bionic hand) in a group.

Health and safety

Teachers should help students cut the cardboard.
Teachers should help students handle the hot glue gun as it is potentially harmful for skin and can cause burns.

→ Summary of activities

activity	title	description	outcome	requirements	time
1	What is inside your hand?	Students will study the human hand.	Students will learn about the role of the bones, muscles and tendons in the human hand.	None	15 minutes
2	Build a bionic hand	Students will build a bionic hand.	Students will build a simple machine and relate its function to the human hand.	Completion of activity 1	30 to 60 minutes
3	Test your bionic hand	Students will test the bionic hand preforming different tasks.	Students will understand the importance of the different components of the bionic hand and relate it to their own hand.	Completion of activity 2	15 minutes

→ Introduction

Bionics is the application of designs and concepts from nature to the development of systems and technology. In medicine, bionics allows the replacement or enhancement of organs or other body parts by human-engineered versions. For example bionic prostheses allow people with disabilities to recover some abilities. Another example of bionics are Humanoid robots which imitate the aspect and functioning of humans.

Figure 1

↑ The ESA DEXHAND developed by the DLR Institute of Robotics and mechatronics

Humanoid robots are proposed to replace humans in hazardous jobs that may cause injury or loss of life. Space is probably one of the most dangerous and damaging environments, in fact many robots are already used for exploration and exploitation of space.

In a near future, it is expected that crews of astronauts and humanoid robots will work together to exploit space. They will both most likely make use of bionic hands. Bionic hands allow robots to manipulate objects made for human use. The astronauts will benefit from bionic hands because manipulation of objects in the vacuum of space through the gloves of a spacesuit is very fatiguing. ESA has developed the DEXHAND bionic hand to be used by robots and possibly by astronauts (see Fugure 1).

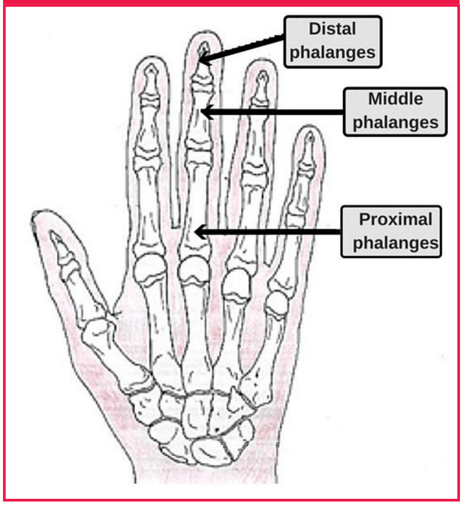
Before starting the construction of the bionic hand lets understand how the human hand works.

The human hand

The human hand is a very complex structure; it contains 27 bones and 34 muscles, along with many tendons, ligaments, nerves and blood vessels, all of which are covered by a thin layer of skin. Each finger consists of three bones (phalanges), which are named according to their distance from the palm: the proximal phalange, middle phalange and distal phalange.

The tendons connect muscles to bones, while the ligaments attach bones to bones. The tendons that help us to move our fingers are attached to 17 muscles that can be found in the palm of our hands and to 18 other muscles in our forearms. The two major actions of fingers – flexing and extending – are carried out by flexor and extensor muscles, respectively. Flexors are joined to the underside of the forearm and extensors are connected to the top of the forearm.

Figure 2



↑ Representation of the bones in a human hand

→ Activity 1: What is inside your hand?

In this activity, the students will learn about the human hand and the role of the bones, muscles, and tendons.

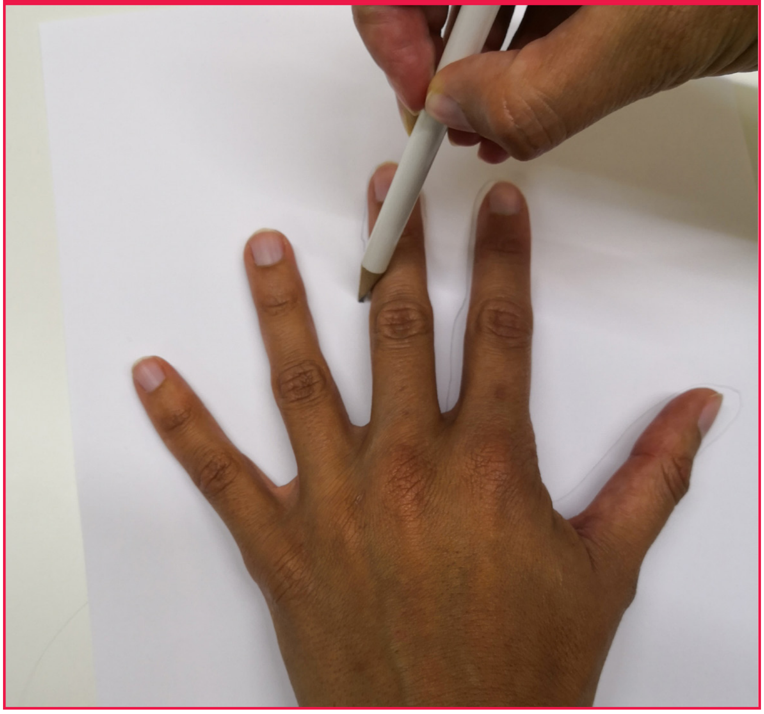
Equipment

- Student worksheet printed for each pupil
- Pencil

Exercise

1. Students must trace a picture of their own hand on a piece of paper or in the student worksheet, like in the example in Figure 3.

Figure 3



↑ Students performing the activity.

2. Students must compare their drawing with the photo of a human hand X-ray and draw the bones of the hand inside their drawing.

3. Students must identify the finger bones and write their names on their drawing.

4. Students should observe their hands and describe the structures inside that help their hands move. Discuss with the students the importance and role of the skin, muscles and tendons, these concepts will be further explored when they build the bionic hand in activity 2.

→ Activity 2 – Build a bionic hand

In this activity, students will learn what a bionic hand is and how it works. They will build their own cardboard bionic hand in groups. The instructions can be found in the Appendix.

Equipment

- Cardboard
- Film tape
- Glue
- Scissors
- Strings
- Rubber bands (thin and thick)
- Straws
- Student worksheet printed for each pupil
- Annex 1 printed for each group

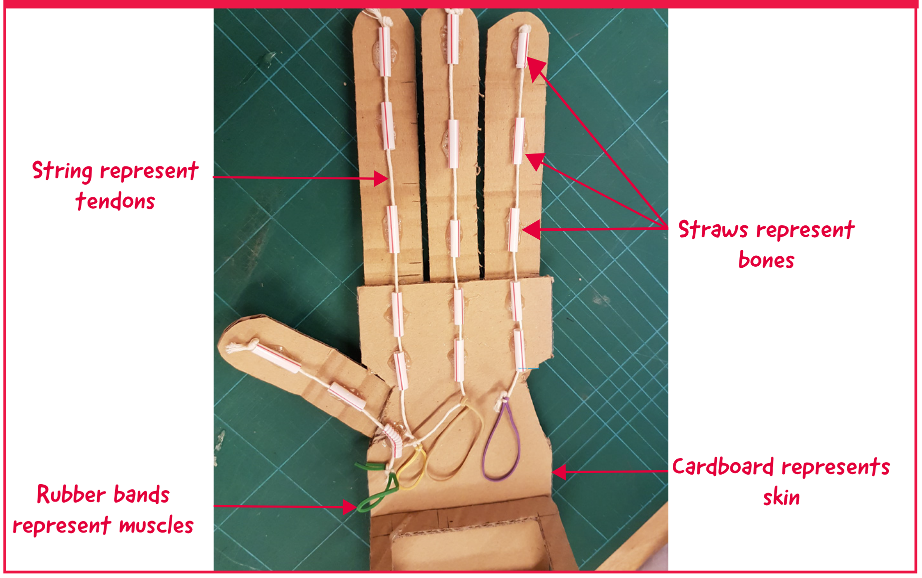
Exercise

This activity is design to be done in a group. Split the students into groups of 2 to 3 students.

Give each group the necessary material to build a model of a bionic hand. Detailed instructions on how to build the bionic hand are provided in Annex 1. Distribute the instructions or project them in the classroom. Depending on the students' age, they may need assistance cutting and gluing the hand. To simplify the assembly the bionic hand can also be constructed using card instead of cardboard.

After building the hand, ask the students to test the hand they have built, they should observe their own hands for inspiration. The students must discuss the differences and similarities between their hands and the bionic hand they built and record their ideas.

Figure 4



↑ Students performing the activity.

The students must also compare their hand and fingers with the hand and fingers of a colleague and discuss what happens when they flex and extend the fingers (with particular attention on the thumb).

In questions 6 and 7, pupils must understand the function of the tendons and muscles in the human hand. Also, the students must compare the role of the straws, the strings, and rubber bands with the function of the muscles and tendons in their own hands, see Figure 4.

→ Activity 3 – Test your bionic hand

In this activity, pupils will perform different tasks with their bionic hand and relate the movements of the bionic hand with their own hands.

Equipment

- Student worksheet printed for each pupil
- Pencil

Exercise

Distribute the student worksheets. Supervise the students during their tests. In this exercise, students should conclude which parameters and structure affects their hand's performance (e.g. how many phalanges, how they fold, how many fingers, etc.). Guide the students to answer the following questions:

1. What items can you pick up with your robotic hand?
2. What would happen if you added more fingers?
3. What would happen if you took out a finger?
4. Why is it difficult to pick up certain items with your robotic hand?

→ Conclusion

These activities are proposed using the IBSE (Inquiry-based Science Education) methodology. Attending the curricula and the age of the students, these activities can be presented as stand-alone modules or integrated into a classroom project. An example of a classroom project of 3 (or more) classes is: ask the students to investigate, by themselves, how the human hand works and the role of the bones, muscles and tendons, using the internet, videos, photos or other resources; build the bionic hand; conclude the project with a visit to a natural museum, to see the differences between human hands and animal paws.

To further explore this topic, this activity can be developed and integrated with others from the Moon Camp kit, namely the Robotic Arm and the Human Body.
For a more complete project on the human body, students can also participate in the Mission X – train like an astronaut challenge.

→ Activity 1: What is inside your hand?

In this activity, you will study your hand.

Exercise

1. Trace your own hand inside the box

2. Compare your drawing with the X-ray photo of a human hand shown below. Draw the bones inside the trace of your hand.

Figure A2

↑ X-ray image of a human hand

3. On your drawing, identify which bones correspond to the fingers and write their names.

4. Observe your hand. Can you identify other structures in your hand besides the bones?

→ Activity 2: Build a bionic hand

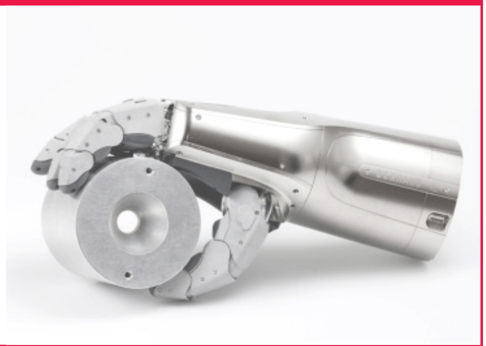
In this activity, you will build your bionic hand and understand how it works.

Equipment

- Cardboard
- Film tape
- Glue
- Scissors
- Strings
- Rubber bands (thin and thick)
- Straws

Did you know?

In a near future, it is expected that crews of astronauts and humanoid robots will work together to exploit space. They will both most likely make use of bionic hands. Bionic hands allow robots to manipulate objects made for human use. The astronauts will benefit from bionic hands because manipulation of objects in the vacuum of space through the gloves of a spacesuit is very fatiguing.



Exercise

1. Check the equipment list and confirm that you have all the necessary materials to build your bionic hand.
2. Follow the instructions provided by your teacher. Build your bionic hand model.
3. Observe how the fingers move. Look closely at the thumb.
4. Your model must be similar to the one shown in Figure A3. Compare your bionic hand with your hand. With your peers, discuss the differences and similarities. Record your ideas on the next page.

Figure A3

↑ Bionic hand built in cardboard

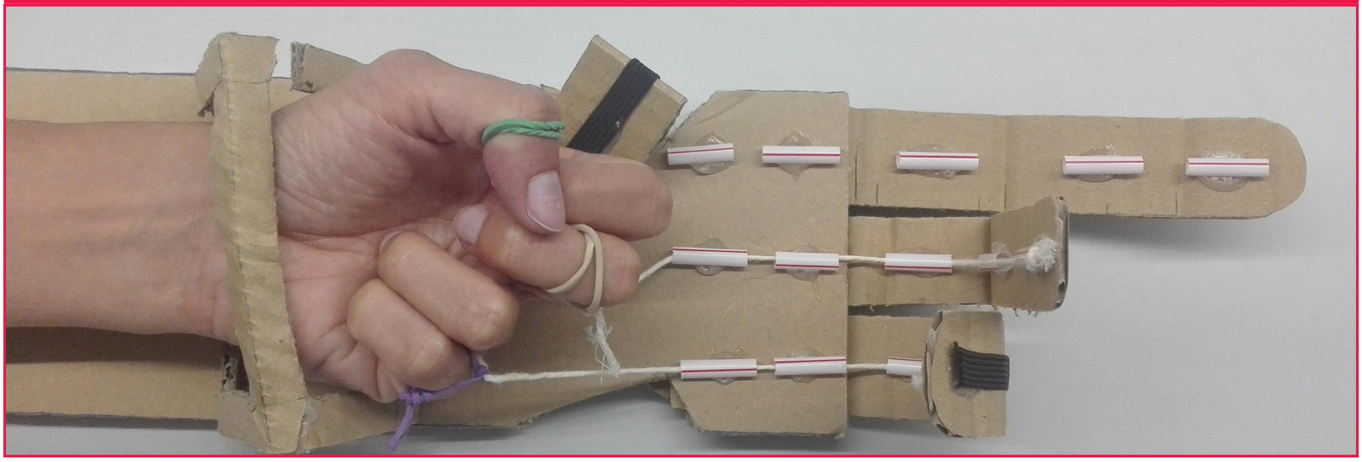
Figure A4

↑ Hand used as model for this bionic hand (same scale)

5. Observe your own hand and fingers, and/or the hand and fingers of one of your peers. Flex and extend your fingers and thumb. Try to understand which muscles and tendons are moving when you do so.

6. Observe the next photo:

Figure A5



↑ Hand using the bionic hand.

Why is the index finger not working well?

7. Exchange points of view with your classmates about the role of each one of the materials used to build the bionic hand, like the straws and rubber bands, and compare their role with the function of the muscles and tendons in your hand. Write down your thoughts and conclusions.

→ Activity 3: Test your bionic hand

In this activity, you will perform different tasks with your bionic hand and test its functionality in different situations.

Exercise

1. Within your group find the answers to the following questions. Record them below:
   a. What items can you pick up with your bionic hand?

   b. What would happen if you added more fingers?

   c. What would happen if you removed a finger?

   d. Why is it so difficult to pick up certain items with your robotic hand?

2. Now, try the following exercise:

Fold your thumb in toward the palm of your hand. Wrap a piece of masking tape around your hand to immobilize your thumb. If you prefer, you can use a glove to hide your thumb. Now, try to perform several daily tasks without using your thumb.

a. Do you think you are able to tie your shoes, to button up your shirt/blouse, or to tighten your belt?

b. Try holding a pencil. Is it easy? Do you think you can you catch a ball?

c. Can you explain why the thumb important?

3. Now imagine you are an astronaut on the Moon. What could you use a real bionic hand for?

→ LINKS

ESA resources

Moon Camp Challenge
esa.int/Education/Moon_Camp

Moon animations about Moon exploration
esa.int/Education/Moon_Camp/Working_on_the_Moon

ESA classroom resources
esa.int/Education/Classroom_resources

ESA Kids
esa.int/esaKIDSen

ESA space projects

ESA Automation and robotics: www.esa.int/Our_Activities/Space_Engineering_Technology/Automation_and_Robotics/Automation_Robotics

ESA Telerobotics and Haptics lab: www.esa-telerobotics.net/

The DEXHAND is a multi-finger robotic hand designed for on orbit servicing in space:
www.dlr.de/rm/en/desktopdefault.aspx/tabid-11669/20391_read-47708/

Hand controller device: www.esa.int/Our_Activities/Space_Engineering_Technology/Hand_Controller_Device

Moon Village: Humans and robots together on the Moon: www.esa.int/About_Us/DG_s_news_and_views/Moon_Village_humans_and_robots_together_on_the_Moon

Extra information

Sophie's Super Hand, an example of a 3D printed prostetic hand:
www.vimeo.com/151718118

How a robot arm in space inspired tech for surgery on Earth:
www.space.com/39899-space-robotic-arm-inspires-surgery-tool.html

→ ANNEX

Instructions to construct the bionic hand

Confirm that you have all the equipment (Figure X1), which was previously listed in Activity 2.
Cut two equal large strips of cardboard (pieces 1 and 2). They should have more or less the length of your forearm and the width of your hand. On each piece, cut symmetric triangles on both sides of one end of the piece (Figure X2).

Figure X1

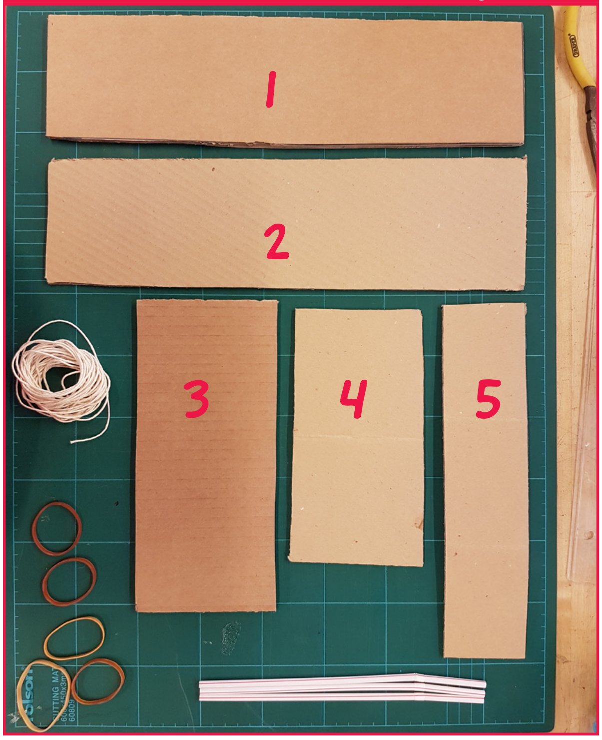
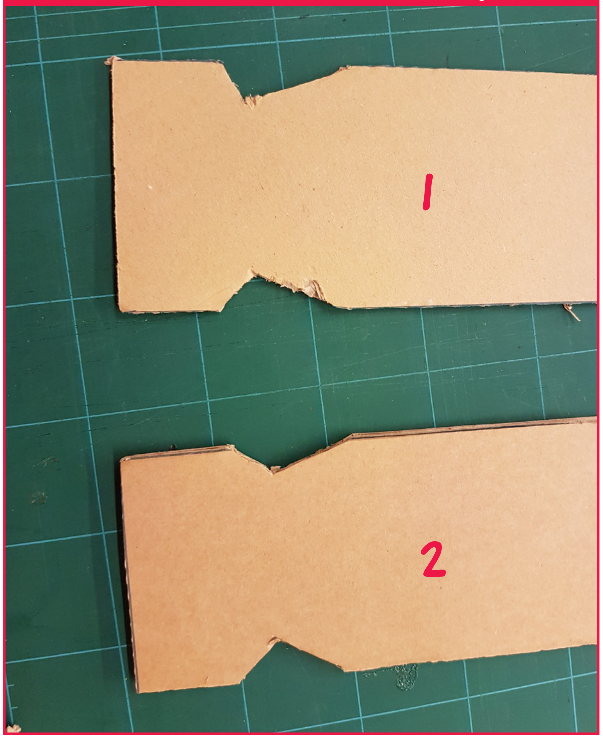


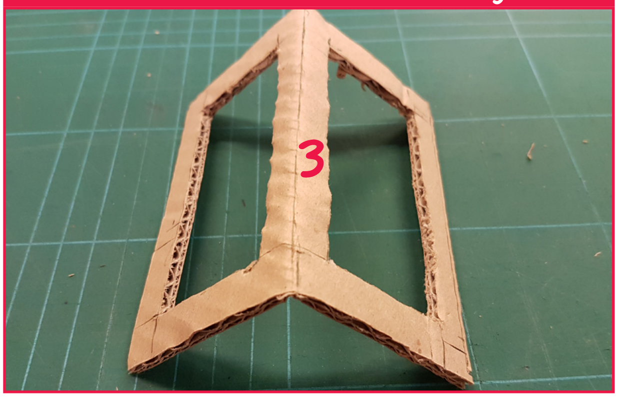
Figure X2



Cut Piece 3, which will be used to build the handle. Mark the cardboard with a pen or a pencil as indicated in Figure X3 and then cut the strip as shown in Figure X4.

Figure X3

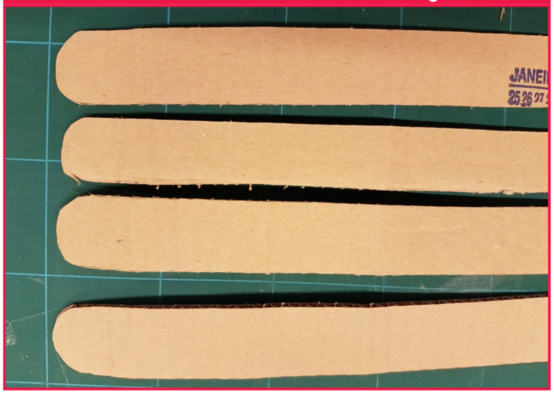
Figure X4



Let's build the fingers now. Cut 4 strips of cardboard as shown in Figure X5 from piece number 5 in Figure X1. Round one side of their extremities (Figure X6).

Figure X5

Figure X6



Use piece 4 (Figure X1) to build the arm support and bend it 4 times as shown in Figure X7. It should have the same width as pieces 1 and 2.

Use hot glue to attach the arm support to the uncut side of one of the two large strips (piece 1). Now glue piece 2 to the underside of piece 1 to form the forearm (FiguresX8, X9, X10 and X11).

Figure X7

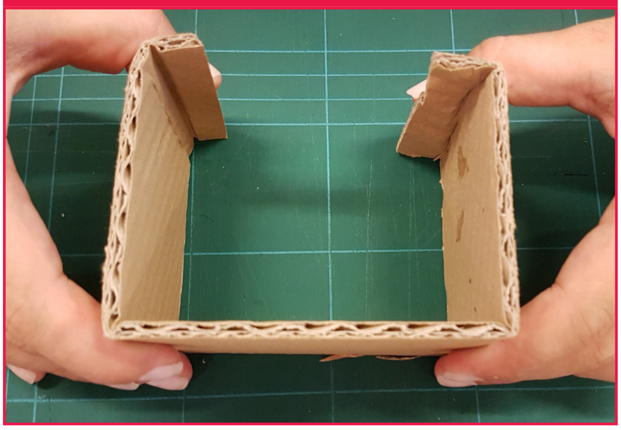


Figure X8

Figure X9

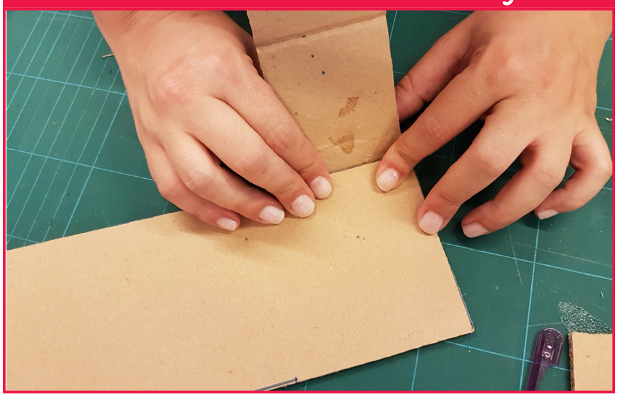


Figure X10

Figure X11

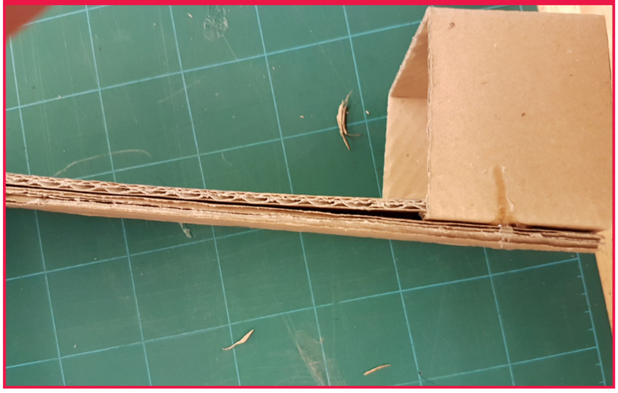
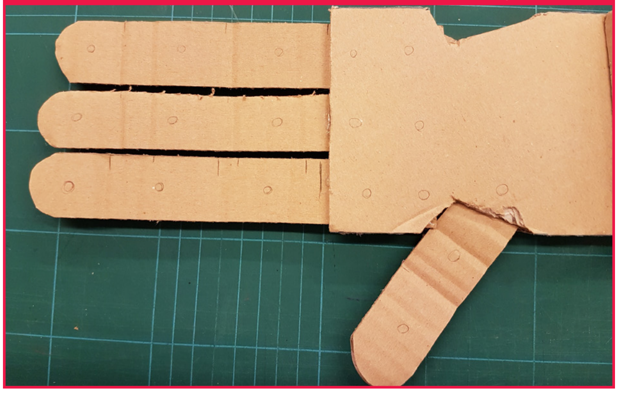


Figure X12



Use the hot glue to attach the fingers you made previously to the cut ends of the arm (Figure X12).

Glue the handle to the arm (Figures X13 and X14).

Figure X13

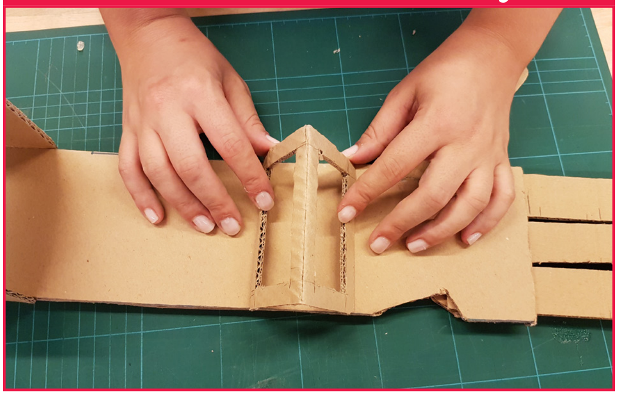
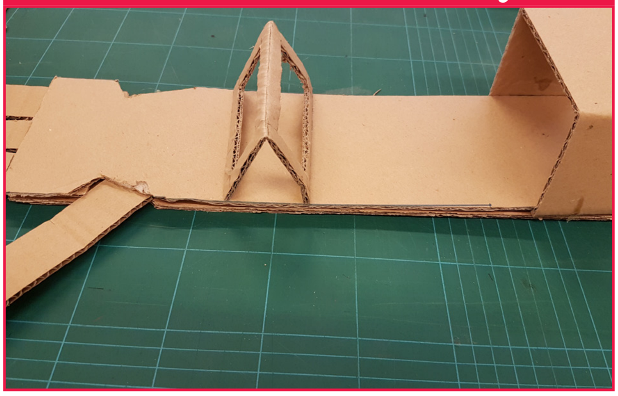


Figure X14



Cut the straws into small pieces, as shown in figure X15. Complete the fingers as shown in Figures X16 and X17.

Figure X15

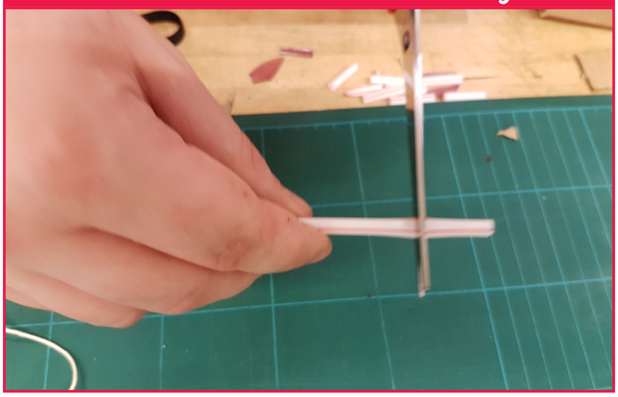


Figure X16

Now, take a string and tie a knot big enough so that it will not pull through the straw. Thread the string through all of the straws on one finger (Figure X18). At the end of the string, tie a thin rubber band (Figure X19). Repeat this step for all fingers (Figure X20).

Figure X17

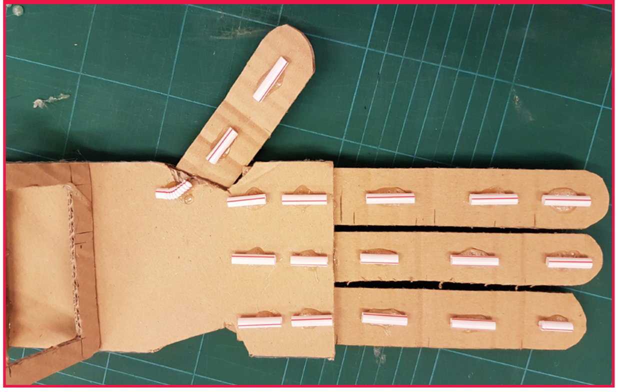


Figure X18

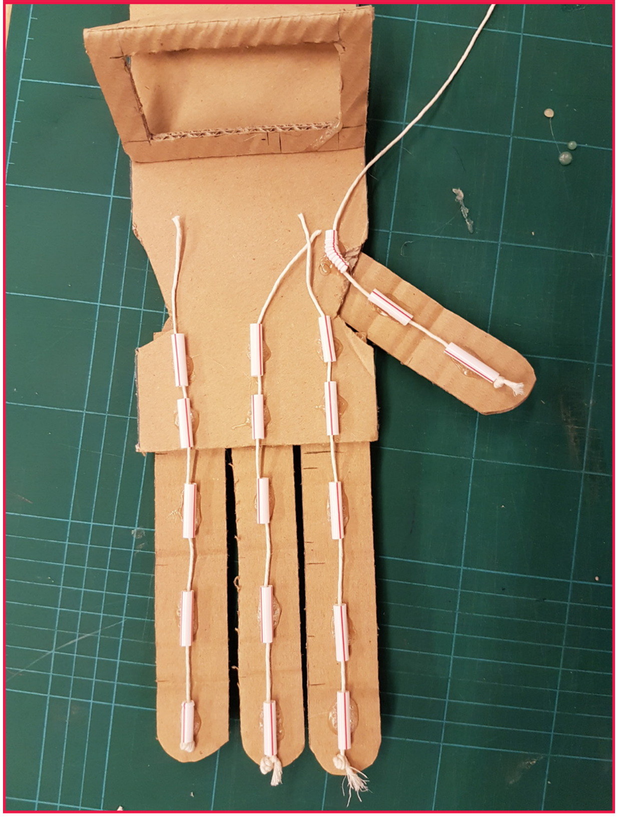


Figure X19

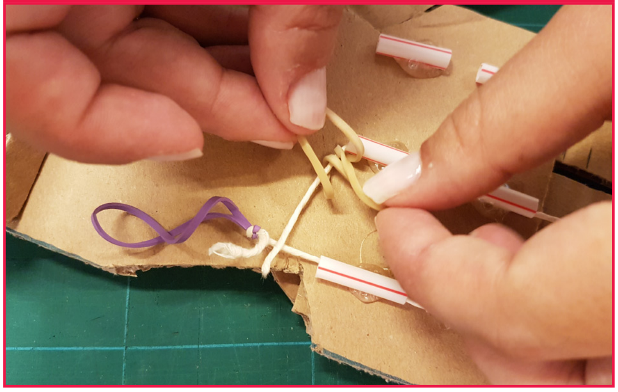
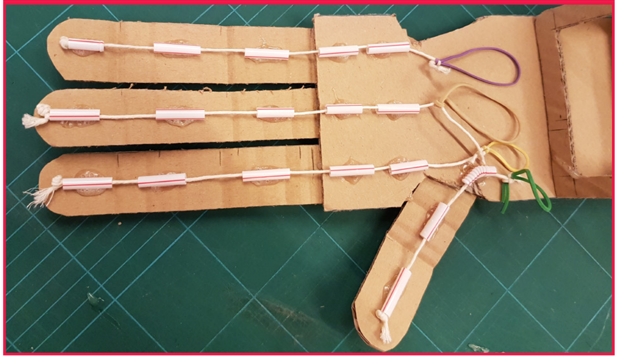


Figure X20



Finally, cut thick rubber bands and glue one onto each of the fingers on the other side of the hand (Figure X21). This will help provide some resistance when moving the hand.

Figure X21

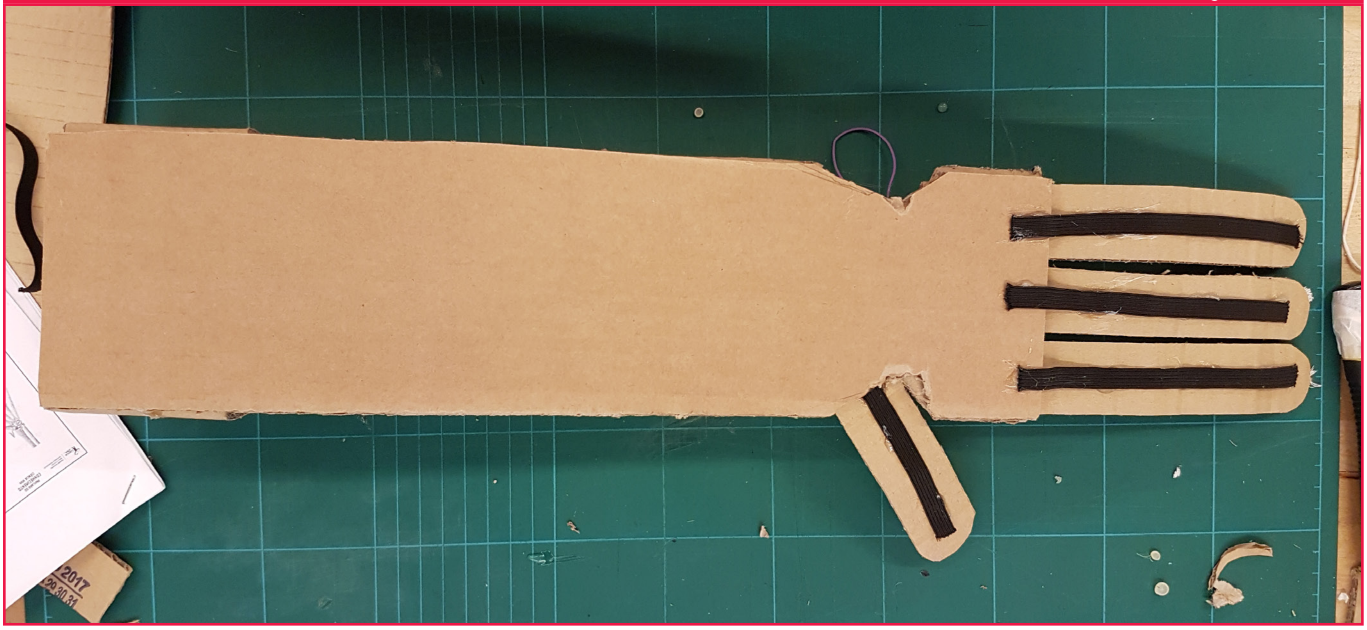


Figure X22