teach with space

→ WATER ON MARS?

Programming a LEGO rover to study changes of state

teach with space – water on mars? | T02
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Fast facts

Age range: 12-16 years old
Type: hands-on inquiry-based activity
Complexity: easy
Teacher preparation time: 15 minutes
Lesson time required: 5 periods of 45 minutes
Location: indoor (room space to test robots)
Includes use of: LEGO Education Mindstorms EV3 (one core set, one expansion set and one temperature sensor for 1 group of students), freezer, ice or dry ice
Keywords: Rover, Mars, mission, program, sensor, change of state, temperature

Outline

Students will design and develop an entire space mission to Mars. The objective of the mission is to send a programmed LEGO rover to the surface of the Red Planet and study water state changes. Students will take temperature measurements and interpret the data collected to understand how the temperature of a substance evolves during a change of state (liquid to solid and solid to liquid).

Students will learn

- To program a robot to reach a location
- To collect data with a temperature sensor
- To use robotic tools to explore scientific content
- To develop scientific experiments and engineering skills, for determining and controlling individual experiment parameters
- To design an experimental procedure to observe different types of state changes
- To identify temperature steps on a graph
- To schematise state changes
- To model data or processes to answer scientific questions
- To work and communicate together as a team

Additional information

In order to replicate the surface of Mars in the classroom and perform the activities included in these resources in a more engaging way you can produce a 'Mars carpet'. For this, all you will need is a high resolution image of the surface of Mars (download here). In ours, we have used a 4 x 2.5 metres mat made out of 510-grams frontlit (typical material used in banners) in order to ensure the necessary traction for the rovers.

→ Summary of activities

Summary of activities				
	Title	**Description**	**Outcome**	**Requirements**
1	Is there water on Mars?	Identifying characteristics of Mars and the different states of matter.	To clarify the students' preconceptions about Mars and the various states of matter.	None
2	How is a mission managed?	Determining the steps of a mission using a scientific approach.	To identify and plan the processes necessary for a successful mission.	None
3	How do you collect temperature data?	Using basic LEGO programming to arrive at the experiment location.	To develop and justify a strategy to program and determine experiment parameters.	Activity 3 of ESA teach with space - build your mars exploration rover | T01
4	How does temperature evolve during a change of state? (I)	Recording temperature as a function of time with the help of LEGO sensors.	To model the dynamic graph of temperature and analyse temperature steps.	Activity 4 of ESA teach with space - build your mars exploration rover | T01
5	How does temperature evolve during a change of state? (II)	Recording temperature as a function of time with the help of LEGO sensors.	To model the dynamic graph of temperature and analyse temperature steps, by applying knowledge from previous activities.	Activity 5 of ESA teach with space - build your mars exploration rover | T01
6	How do you complete a mission successfully?	Determining skills and knowledge acquired.	To answer a scientific question, synthesise concepts and self-evaluate.	None

→ WATER ON MARS?

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→ Activity 1: Is there water on Mars?

This activity tasks students discuss what they already know and further investigate the Martian environment, by comparing several parameters to those here on Earth.

Exercise

1. Allow students to discuss and back-up their predictions with arguments, using what they already know about Mars from their studies, the news, and general knowledge to support them. You may wish to then ask the students to use the internet to research the correct answers or provide them. You should discuss the consequences of the differences between Martian and Earth conditions and particularly what it means for the existence of life (as we know it) and water.

	Mars		Earth
	Prediction	Actual	
Mean temperature		-63°C	15°C
Minimum temperature		-153°C	-90°C
Maximum temperature		20°C	55°C
Diameter		6779 km	12700 km
Gravity		3.8 m/s²	9.81 m/s²
Atmosphere		95% CO2, 2.7% N2, 1.6% Ar, 0.2% other gases (this varies slightly depending on the source, but be sure to emphasise the main differences)	N2 78%, O_2 21%, 1% other gases
Atmospheric pressure		600 Pa	100 KPa
Days in a year		687	365.25
Highest mountain		21287 m (Olympus Mons)	8848 m

2. There are many examples that could be used here. The most common examples students will use are likely to be related to the boiling and freezing of water due to the weather, cooking etc. Be sure to enforce the correct use of terminology for the associated changes of state.

3. The main features to be discussed here are:

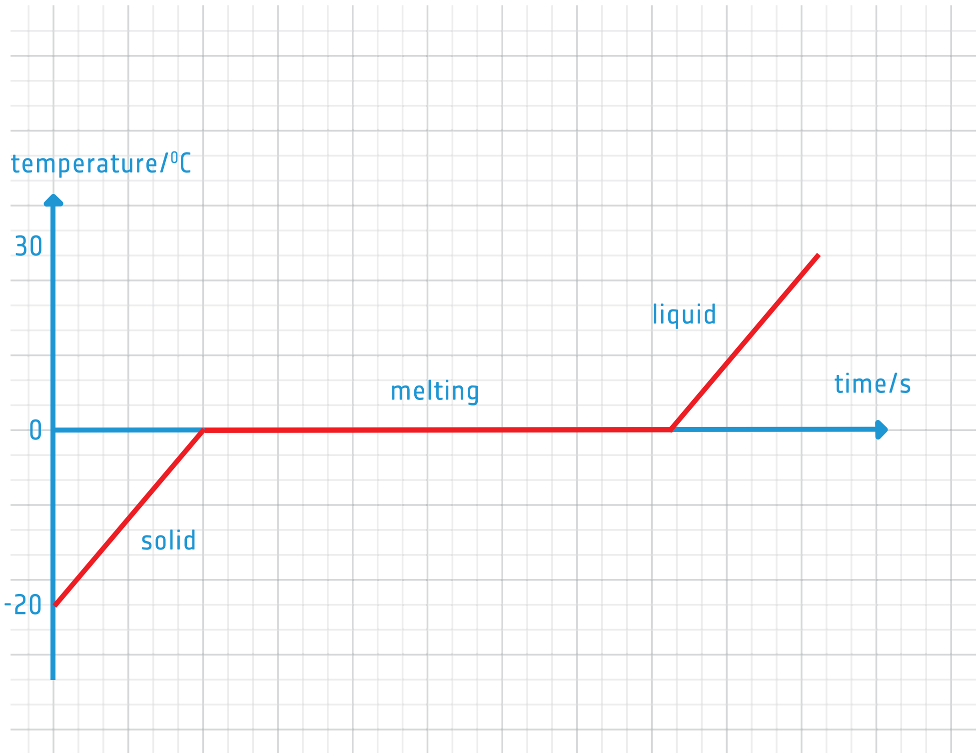
- The body of frozen 'water' inside the crater in the left image
- The channel carved into the surface in the right image
    - ◊ What processes could have caused this?
        - » Whilst we can't be sure, one interpretation of this is that the channel is in fact an ancient riverbed that may have carried water at some point in Mars' past.

This is a good opportunity to discuss the consequences of the parameters in question 1. In today's conditions, could water flow through this riverbed? Why not? What other substances could be in liquid form?

4.

1. Sublimation
2. Reverse sublimation
3. Condensation
4. Evaporation
5. Melting
6. Freezing

5. Depending on the substance chosen the temperature values for the changes of state will vary, but the shape should remain the same. The example below is for H_2O.



↑ Note: This is a simplified example, actual experimental data is unlikely to give such a clear transition!

→ Activity 2: How is a mission managed?

Here you will discuss with the students the main aspects of mission, from conception to delivery. In this case the mission is to investigate states of matter.

Exercise

Allow for creativity to flow when designing the mission objective, but be sure to critically question throughout. Is it a feasible idea? Does it tackle the main objective of investigating the states of matter?

→ Activity 3: How do you collect temperature data?

This activity gives students the opportunity to use the LEGO EV3 Mindstorms and its software to collect temperature measurements. In order to complete this, students should already be familiar with the main functions of the Mindstorms software.

Exercise

1. As with any problem solving task, there are many different solutions here. To collect data, students may choose to log it to a file for later analysis, using the blue data blocks or collect live data using the experiment window. Both are viable options, however using the experiment view allows for faster viewing and analysis of the data!

2. The values chosen depend on the environment of the classroom, and how long they wish to collect data for. This is also a good opportunity to demonstrate how the scale can make it easier or more difficult to carry out analysis. For example, utilising as much of the screen space as possible.

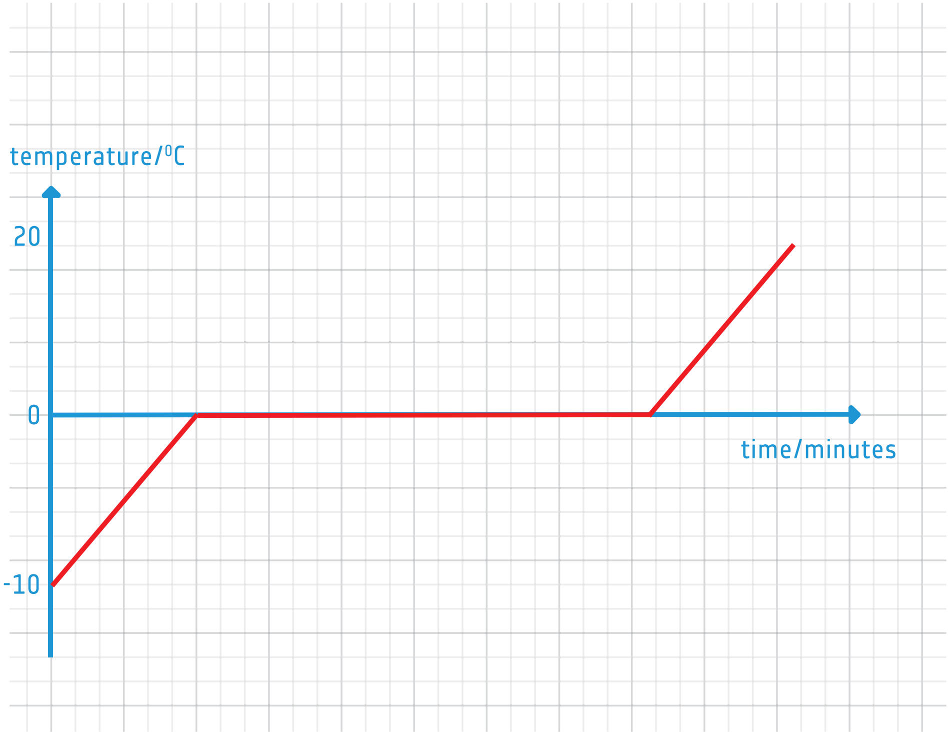
→ Activity 4: How does temperature evolve during a change of state? (I)

This activity can either be followed in the student sheets, or carried out by the students, allowing them to use and analyse their own data instead. Temperature data is recorded for water through freezing and melting, over 15 minutes, and students are tasked with determining what each stage of the graph shows. To replicate this activity in the classroom you can use a container filled with ice, and make a few holes on the surface of the container in order to allow the rovers to insert the temperature sensors and measure temperature.

Exercise

Ice is the section between 5 and 6 minutes that ranges from -10°C to 0°C, and extends through to approximately 11 minutes, as the ice melts to water. A common mistake here will be thinking that the ice phase ends once the temperature reaches 0°C.
From approximately 11 minutes onwards, the water is in liquid form, and the temperature steadily rises to around 20°C.

2. Here the students are tasked with recreating a similar graph to that shown in Activity 1, exercise 5, like this:



3. The correct sections of this graph are A-D, though it is worth point out that the full section from C-D has not been carried out, as the temperature only reaches 20°C. The students should be able to correctly identify that the end of the C-D section is at 100°C.

4. Here the students should use the terminology discussed in Activity 1, exercise 4, and suitable temperatures should be added to the y-axis. It is worth pointing out that the scale of the x-axis of time depends largely on how the experiment is carried out, but the shape of the curve should remain the same regardless of how slow or fast the water is heated.

→ Activity 5: How does temperature evolve during a change of state? (II)

This is a simple extension of the first section of this activity, that now tasks the students with correctly identifying the elements of the cooling and freezing section of the graph,

Exercise

1. Ensure that the students model has suitable axes and that the values of the transitions refer correctly to those of water. Again, stress here that the time axis is mostly dependent on the cooling method

→ Activity 6: How do you complete a mission successfully?

In the final activity, students revisit the mission statement and steps they identified in Activity 2.

Exercise

The answers here will vary from student to student, but ask them to reflect on what they have learnt about changes of state, and whether or not they have answered the question they set out to answer in Activity 2.

→ Activity 1: Is there water on Mars?

Mars has always captured the imagination of humankind, sparking interest from scientists and artists. During the last 2000 years, Europeans have made many important observations of the Red Planet. What do you know about Mars?

Figure A1

↑ Mars as seen by ESA's Mars Express.

Exercise

1. Compare Earth and Mars using the various characteristics you see in Table A1. In the 'Prediction' column, write your predictions for Mars compared to Earth using the symbols: '=', '>', or '<'. Find out all you can about Mars, and then complete the 'Actual' column with the real values of Mars' characteristics. Compare them with your predictions.

	Mars		Earth
	Prediction	Actual	
Mean temperature			15°C
Minimum temperature			-90°C
Maximum temperature			55°C
Diameter			12700 km
Gravity			9.81 m/s^2
Atmosphere			N2 78%, O_2 21%, 1% other gases
Atmospheric pressure			100 KPa
Days in a year			365.25
Highest mountain			8848 m

↑ Table A1: Comparison of Mars and Earth.

2. During your daily life you often observe matter in its different states. You also sometimes see the transition between these states. Give an example of a transition and write down what you propose to be the cause (your hypothesis) for the change of state.

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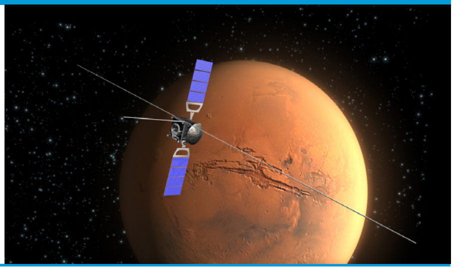
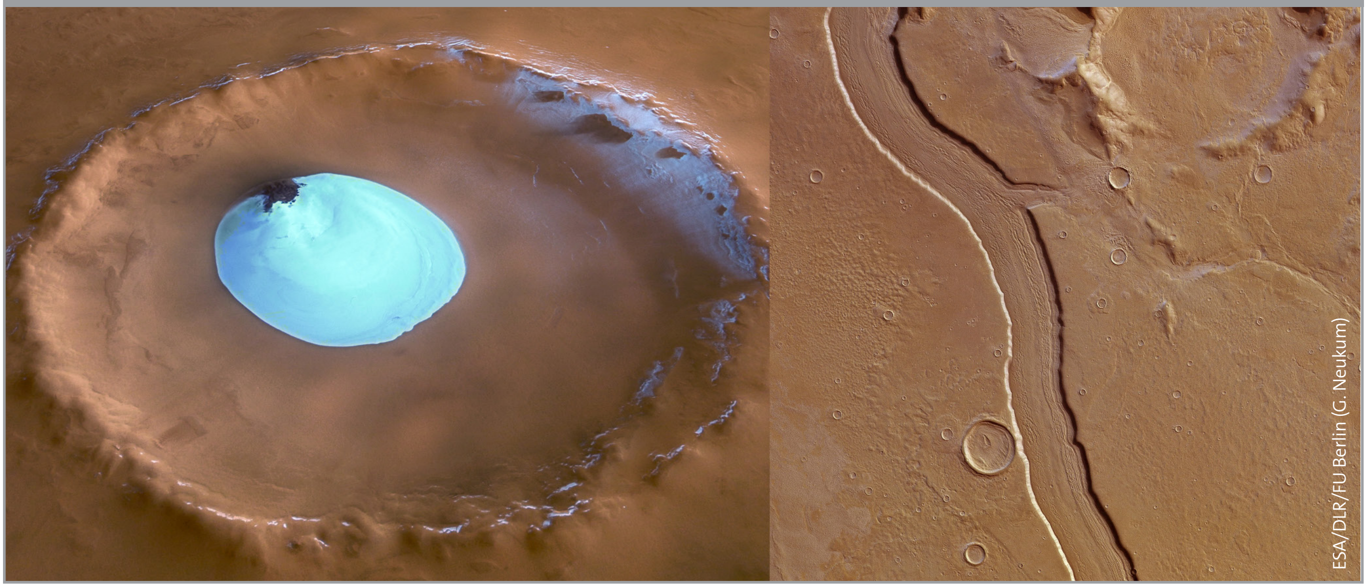
Did you know?

ESA's Mars Express mission, launched in 2003, studies Mars in a wide range of wavelengths (including visible, radio, and infrared), and takes pictures of the Martian surface. It was the first spacecraft to show that the surface of Mars displays a fascinating variety of minerals.



3. Using the images of Mars taken by the ESA's Mars Express satellite (Figure A2), complete Table A2 with your observations and interpretations.

Figure A2



↑ Mars as seen by ESA's Mars Express

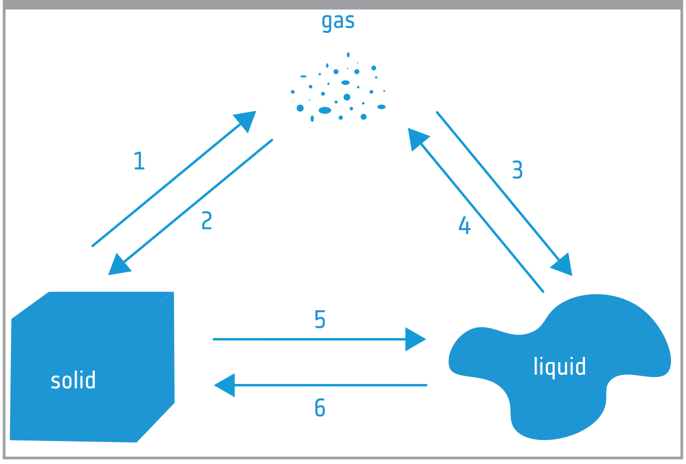
Observations	Interpretations

↑ Table A2: Mars surface observations vs interpretations.

4. The changes between different states are represented in Figure A3. Name each phenomenon, numbered from 1 to 6, with its correct term:

1.
2.
3.
4.
5.
6.

Figure A3



↑ Dynamic representation of changing states.

5. A change of state is caused by a change in temperature and/or pressure. On the grid below, plot your prediction for how the temperature of a system will change as a function of time, for a transformation from a solid state to a liquid state. Label the graph to show when the state is solid, and when it is liquid. Do not forget to give titles to your graphs and to indicate the units on each axis.

In the next few activities, you will investigate changes of state as a result of changes in temperature You will find out whether your prediction in the graph above is correct.

→ Activity 2: How is a mission managed?

Planning a space mission means defining scientific objectives by first formulating a scientific question . The objective of the mission will be to answer this question.

Exercise

1. After discussing it with your teacher, formulate a research question to investigate states of matter:

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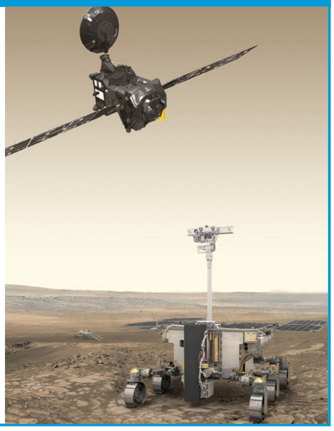
Did you know?

The ExoMars programme consists of two missions. The first one, launched in March 2016, consists of the Trace Gas Orbiter which is now in orbit around Mars, and the Schiaparelli demonstrator which is now on the surface. The second, to follow in 2020, features the Rosalind Franklin rover and a Russian, experiment-filled surface platform. A number of important scientific investigations will be carried out, such as searching for signs of past and present life on Mars, investigating how the water and geochemical environment varies, and investigating Martian atmospheric trace gases and their sources.



2. In order to achieve your mission objective you must first structure your mission. Identify the various steps necessary for you to complete the mission successfully.
   In Table A3, describe the different steps of your mission:

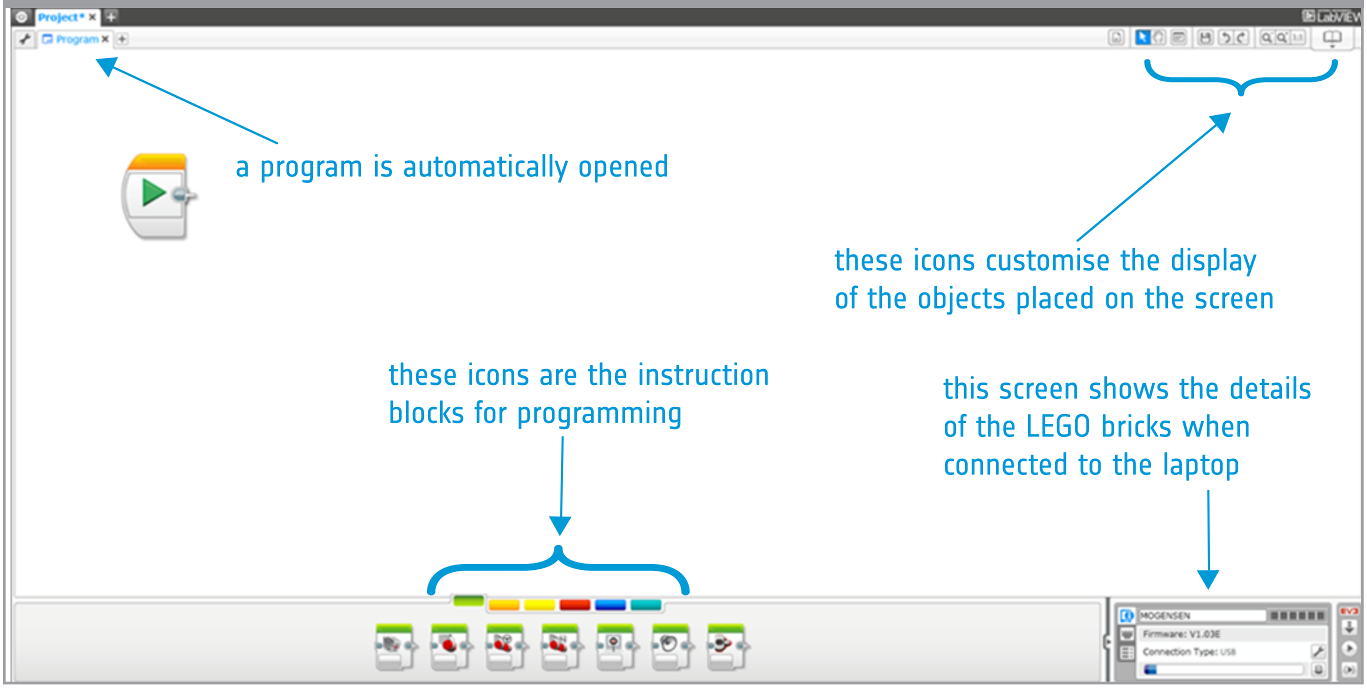
Steps	Description	Skills / knowledge requirements

↑ Table A3: Mission steps.

→ Activity 3: How do you collect temperature data?*

Build a LEGO robot or take one that is already built and connect the temperature sensor to port 1 on the LEGO brick. Launch the LEGO Mindstorms EV3 Education software to program the LEGO-built robot and create a new program.

Figure A4



↑ LEGO programming window.

Exercise

1. By assembling the instruction icons, develop a program that will reach a location and develop a system that will enable you to measure the temperature on Mars. Be creative! Write down your strategy:

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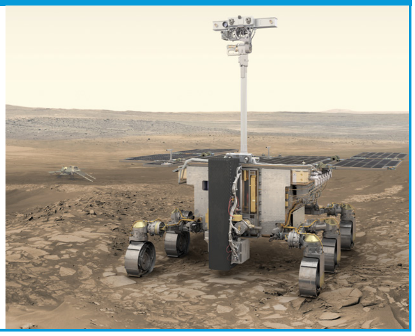
* Requirement: Activity 3 of ESA teach with space - build your mars exploration rover | T01

Did you know?

The ExoMars 2020 mission will deliver a European rover and a Russian experiment-filled surface platform to Mars. The rover will be the first mission to move across the surface and drill down to a depth of 2 m. The collected samples of Martian rock will be analysed in the rover's onboard laboratory. Underground samples are more likely to include biomarkers (the chemical signatures of life, past or present), since the tenuous Martian atmosphere offers little protection from cosmic radiation and light from the Sun.



2. Open a new experiment by clicking on the '+' symbol at the top left of your 'project' screen. Display the temperature sensor on the y-axis and define its scale for the experiment. Connect the brick to the laptop via a Bluetooth connection.

Figure A4

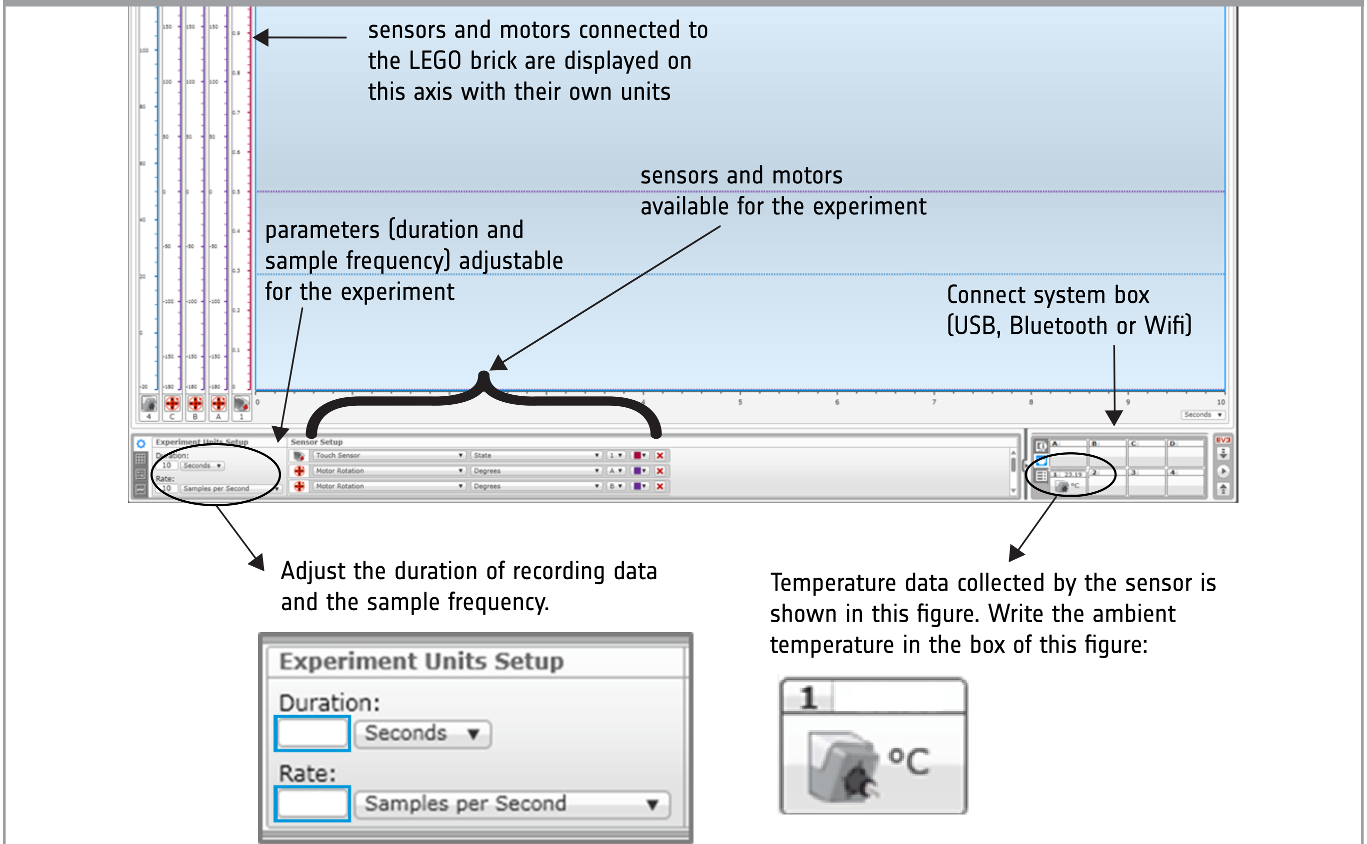


Image 8. LEGO experiments units setup

↑ LEGO experiment window.

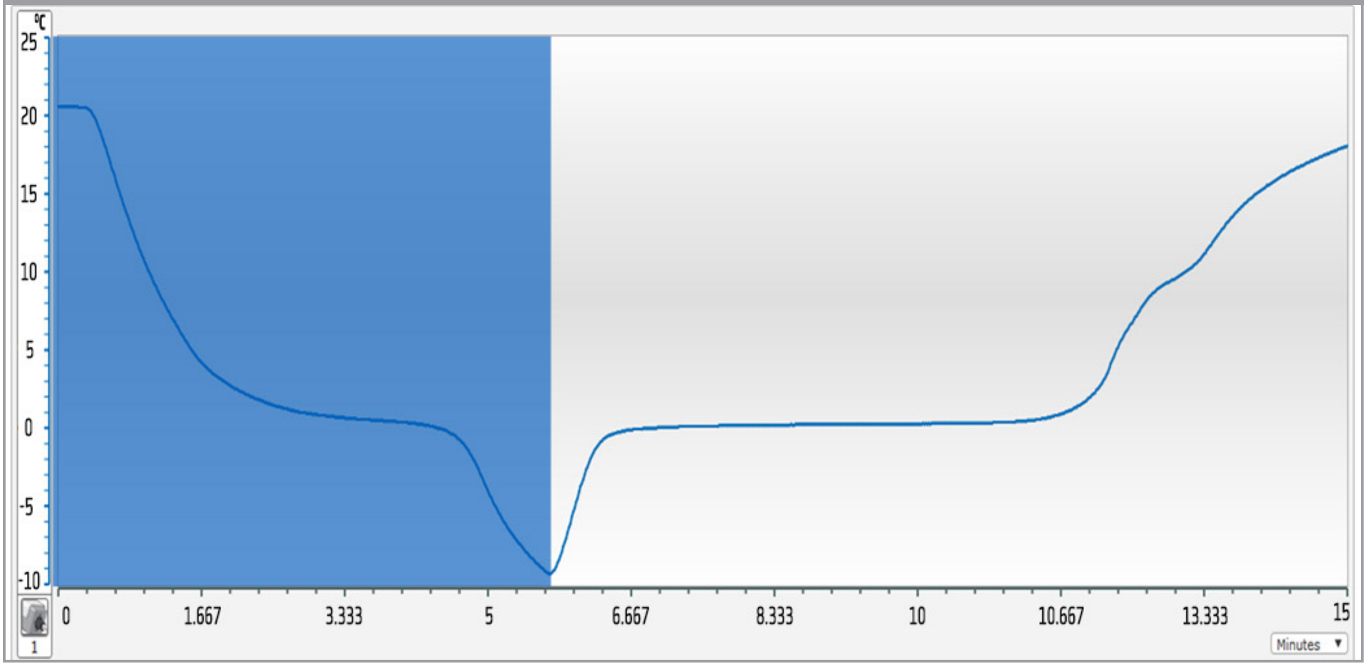
3. Justify the values you have selected for the temperature scale, sample frequency and duration of the recording. Now that the experiment is concluded, do you think they were relevant choices?

→ Activity 4: How does temperature evolve during a change of state? (I)*

Exercise

1. Dynamic temperature data recorded by the sensor is plotted in Figure A5. Regarding the second section of the curve(the white area) and knowing that the matter studied is water:
- associate a temperature range to each of the different states
- indicate their names
- identify the change of state.

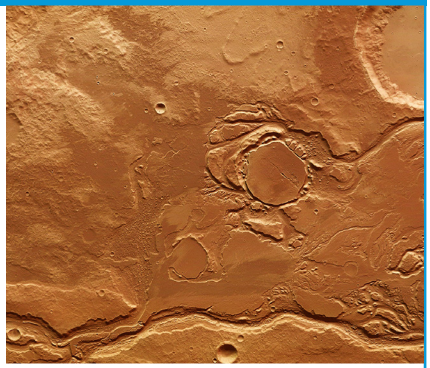
Figure A5



↑ Dynamic temperature data of water, second section

* Requirement: Activity 3 of ESA teach with space - build your mars exploration rover | T01

Did you know?



Changes in the state of water depend on its temperature and pressure. Compared to Earth, the pressure on Mars is too low for pure water to exist in a liquid state at the surface. It is possible that liquid water could exist on Mars deep underground. It seems that in the past Mars was warmer than it is now, with a thicker atmosphere. Scientists are no longer looking for intelligent beings on the Red Planet, but for biomarkers which could provide evidence that there was once liquid water either on the surface or under the surface.

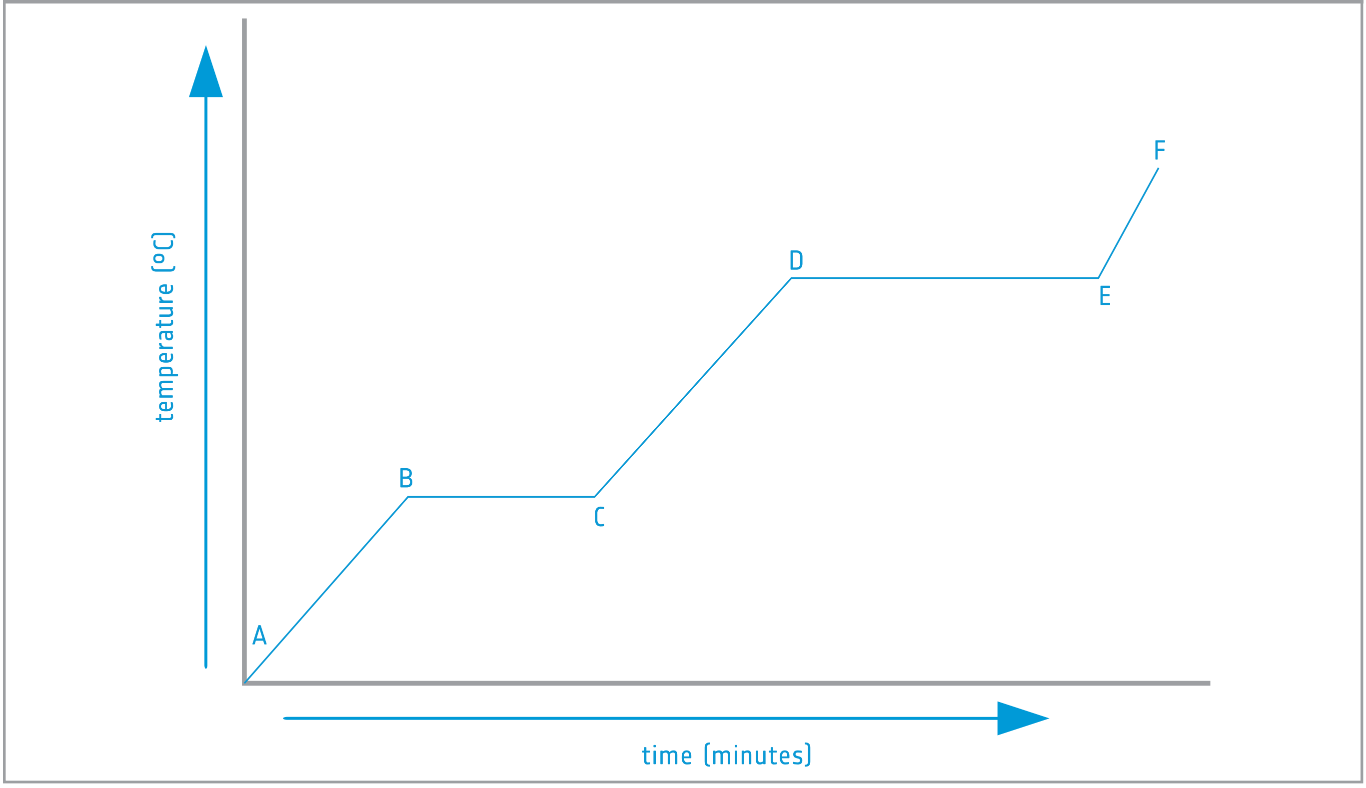
2. In science, a model is a representation of a phenomenon that helps us understand observations. A simple model explains one dimension of a phenomenon (for instance the evolution of temperature) and can be built after collecting data.

   In order to create a model that is easy to understand, simplify the curve section in Figure A5 by using straight, connected lines to represent the different states of matter and the transition between them. Do not forget to give a title to your graph and indicate the units on each axis.

During your experiment, you collected temperature measurements within a limited range. The model plotted in Figure A6 shows temperature measurements within a larger range.

3. Identify your previous experiment area on this model, by drawing a circle around the appropriate letters (choose from A, B, C, D, E and F).

Figure A6



↑ Dynamic temperature model of water

4. Explain the top of the model in Figure A6 using the appropriate vocabulary, and add the key temperatures on the vertical axis.

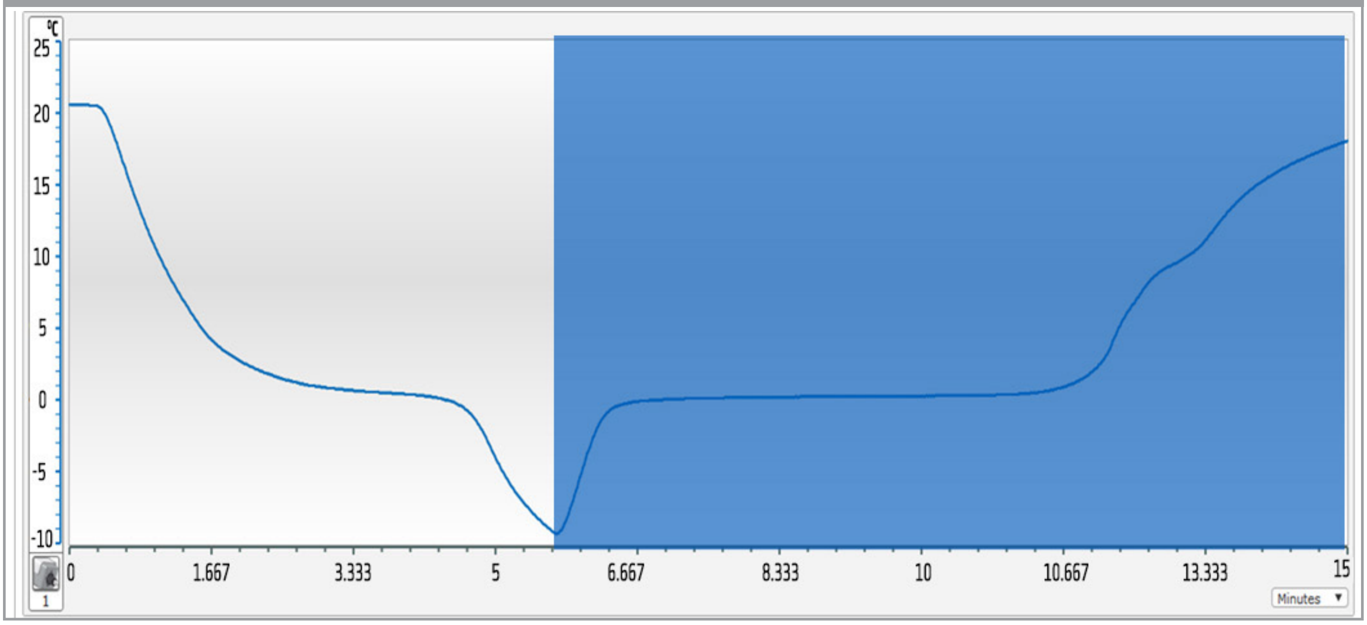
→ Activity 5: How does temperature evolve during a change of state? (II)*

Exercise

1. Looking at the first section of the curve (the white area), and knowing that the matter studied is water:
- associate a temperature range to the states and indicate their names
- indicate the state change
- create a model of this part of the experiment in the grid below

Do not forget to give titles to your graphs and to indicate the units on each axis.

Figure A7



↑ Dynamic temperature data of water, first section.

* Requirement: Activity 3 of ESA teach with space - build your mars exploration rover | T01

→ Activity 6: How do you complete a mission successfully?

Exercise

1. Complete Table A4 with the skills and knowledge you have acquired at every step of your mission.

Steps	Skills / knowledge requirements

↑ Table A4: Skills and knowledge acquired.

2. To conclude, write down your answer to the scientific question you formulated at the beginning of Activity 2. Use adequate vocabulary to explain the concepts you have learned.