In collaboration with:

TEACHERS' TOOLKIT

Learning wind energy in **primary schools**

Reviewed by the Science Communication Committee of the European Academy of Wind Energy

TEACHERS' TOOLKIT

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ABOUT THIS TOOLKIT

Our aim was to develop a curriculum to teach children about wind energy in primary schools. We were fortunate to have found the perfect partners for this venture at the Singelijn Primary School in Brussels, where this project was created and successfully implemented.

This Teachers' Toolkit is based on the outcome of this project, carried out with a class of 12-year-olds in the 6th grade, from November 2020 to April 2021.

The school felt that this particular age group – 12-year-olds - would be most likely to appreciate and fully benefit from the subject. The background knowledge and competencies of the students who took part are described in detail below and should serve as a clear indicator of what basic know-how is needed to implement this Toolkit successfully.

The curriculum was designed by the schoolteacher and his class of 20 children, and it was adapted to fit into their learning objectives and interests. It links the subjects of **science/technology**, **maths**, **history**, **geography** and **grammar** with wind energy topics. The subject of wind energy has been integrated into the school's pedagogy and the overall school programme.

The teacher leading this project did not have any previous background in wind energy. He was supported throughout the development and implementation phase by two experts (university professors) who helped him to draw up the modules.

This Toolkit is based on the lessons learnt from this pilot project. It takes into account comments and insights from the teacher and students. The Toolkit as a whole was reviewed by the Science Communication Committee of the European Academy of Wind Energy (Technical University of Delft, Technical University of Denmark, Politecnico di Milano, University of Texas, Dallas and the von Karman Institute for Fluid Dynamics).

This Toolkit is designed for any school and any teacher that wishes to teach their students about wind energy.

It does not require teachers to have had any specialised training to implement this curriculum. This programme can be carried out in full or can be used in a piecemeal fashion, adapted to the students' learning objectives.

We are here to assist, should anyone need any help and support.

Let's start!

Watch this video to hear what the teacher and the students had to say about it.

HOW TO USE THIS TOOLKIT: TEACHER'S GUIDE

- The Toolkit has four modules that can be used in sequence or adapted depending on the learning needs:
  - **Module 1**: Learning about energy
  - **Module 2**: Constructing an anemometer and taking measurements
  - **Module 3**: Understanding Wind Turbine Technology
  - **Module 4**: Learning about wind

- Each module includes:
  - A **Lesson Plan**, which lays out the objectives for student learning (knowledge and competences) and the teaching activities. It is meant to help you prepare your own lessons
  - And **Examples of student work**, either in the classroom or as a research project, so you can see what the final product or results might look like (they are in French, but they are only meant to give you a broad outline)

- The activities include individual and group projects and rely on practice and learning by example

- The Toolkit has **Support material** for the teacher, including theoretical aspects as well as diagrams and instructions, prepared by wind energy experts

- It is designed to be used independently, without the need of an outside expert

- For those seeking more background, we have provided links to reliable information resources at the end of this document

BACKGROUND KNOWLEDGE & SKILLS OF 6TH GRADE STUDENTS

The students that this Toolkit could be used for have the following knowledge and competencies in maths, science and physics, as described by their teacher:

Numbers and calculations:

- Decimal numbers, fractions and percentages
- Addition, multiplication and subtraction of large numbers. They need help dividing large numbers

Representing a situation using graphs and reading them correctly:

- Bar graphs
- Line graphs
- Circle graphs/pie charts

Measurements:

- Length from mm to km
- Surface area and volume: m^2 and m^3
- How to use a compass, a protractor and a set square
- Different quadrilateral shapes
- Constructing a cube and a rectangular parallelepiped

Physics:

- Basic knowledge of electricity
- The students haven't yet worked on the concept of speed

I WANT TO TEACH KIDS ABOUT WIND ENERGY IN MY SCHOOL. WHERE DO I START?

This section will show you the steps to design a wind energy curriculum with your students. Doing it together, will help you to create engaging team of students, and use this programme in an optimal way.

You can replicate it as it is or use it for inspiration to make your own curriculum, based on the learning needs, objectives and interests of your students. The time needed to undertake this activity is approximately two (50-minute) classes.

STEP 1
Assessing learning needs

Ask your students to reflect on and answer the following 4 questions, without them doing any previous research:

? **What do I know about wind energy?**

The objective of this question is to assess the level of knowledge the students have on wind energy with the aim of building on it. The teacher can then summarise the answers and put them on a whiteboard for the students to visualise them.

Examples of student's answers:

- Wind turbines are connected to power plants
- The blades rotate thanks to the wind
- It's expensive
- When the blades rotate, they generate electricity that supplies the city
- The blades make an engine work
- It's a green energy
- Electricity goes into a battery where it is stored. From there it goes to the houses.

Why is renewable energy an important issue now?

The objective of this question is for the students to connect it to the broader issues of climate change to understand why they are learning about wind energy. The answers can be discussed in the class and summarised by the teacher on the whiteboard.

Example:

- Pollution
- Global warming
- Green energy

How do I think a wind turbine works?

To answer this question, the students make a drawing to represent how a wind turbine works.

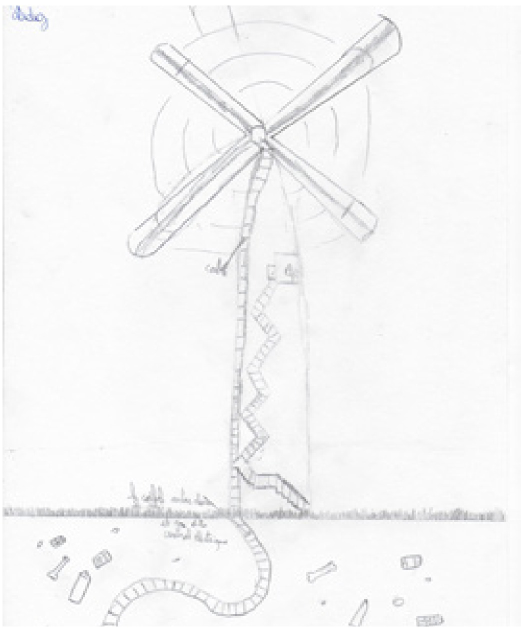
By reflecting on the first three questions, the teacher and the students will be able to work out what they don't know and what they are most interested in learning about.

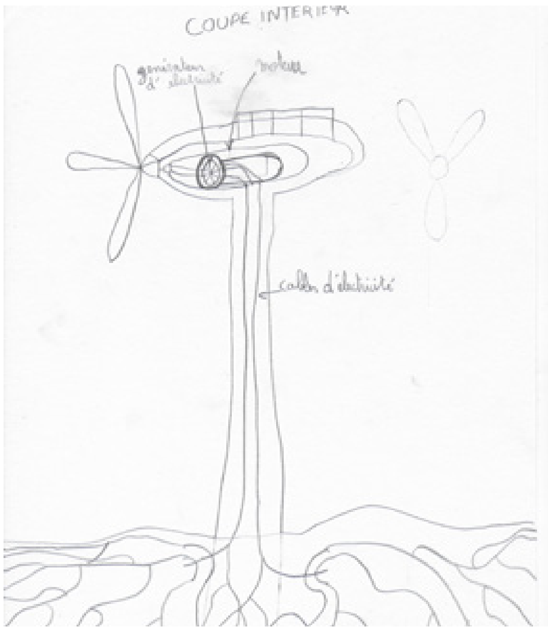
What do I want to learn about wind energy?

Each student answers this question individually. The teacher then pools the answers and discusses with students about what they want and what they need to learn:

- How a wind turbine works; more specifically how the rotation of the blades becomes electricity?
- Who invented it?
- How is it built?
- How much does it cost?
- How does the engine work?
- How do you decide where to put them?
- Comparing wind energy to other ways of producing green energy (solar panel, hydropower...)
- The history of wind
- Where wind turbines are built and the materials they are made of
- Visiting a wind turbine

FIG. 1 & 2
Examples of student drawings:



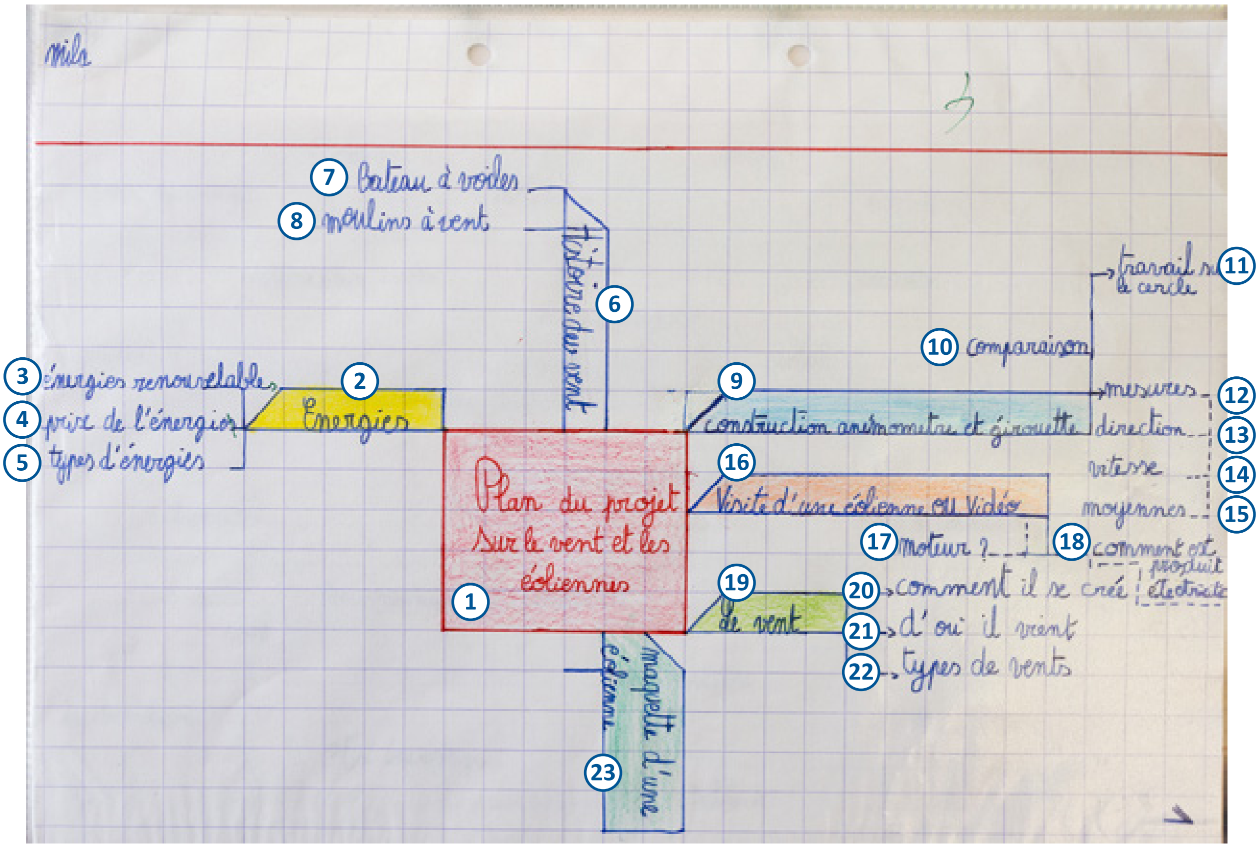


STEP 2

Organising the learning needs

The students arrange their answers to the previous question "what do I want to learn about wind energy" in the form of a plan or mind map, drawn by the teacher and the students on the whiteboard. Each student copies the mind map into their notebook as a reference for future use.

FIG. 3
Example of a classroom mind map



1. Project plan on wind and wind turbines
2. Energy
3. Renewable energy
4. Energy prices
5. Types of energy
6. History of wind
7. Sailing boats
8. Windmills
9. Construction of anemometers
10. Comparison
11. Work on the circle
12. Measurements
13. Direction
14. Speed
15. Averages
16. Visit to a wind turbine or video
17. Motor
18. How is electricity produced?
19. Wind
20. How it is created?
21. Where it comes from?
22. Types of wind
23. Model of a wind turbine

STEP 3
Organising the sequence of the lessons

In this phase, students and their teacher organise the sequence of the activities they will be following:

1. What is energy?
2. The classroom anemometers
3. Using an anemometer
4. The anemometer makes a circle
5. Where does the number Pi (π) come from?
6. My research about the area of the circle
7. My representation of wind energy
8. My observational drawing of a wind turbine
9. My summary of the videos on wind turbines
10. Grammar
11. My note-taking from the videos on wind turbines
12. Building a wind turbine together
13. The wind
14. Our work on aerodynamics
15. The global map of winds
16. Types of wind
17. My representation of the respiratory system
18. My observational drawing of the lung
19. My report on the dissection of the lung
20. My summary of the respiratory system
21. My drawing of the respiratory system
22. The working system of a wind turbine

STEP 4
The Curriculum

The result of these steps can be arranged into the following detailed curriculum. Some activities can be done simultaneously and the sequence can be changed according to the classroom's needs.

TABLE 1

MODULE	LESSON	SUBJECT	DURATION
1. Learning about energy	• Defining energy and its types • Researching energy sources & presenting the research work • Learning about different aspects of wind energy: administrative, economic and environmental	• Physics • Geography • History	• One (50-minute) class for defining energy • 5 days to research energy sources at home • Two (50-minute) classes for learning about different aspects of wind energy
2. Constructing an anemometer and taking measurements	• Constructing an anemometer • Using an anemometer to measure wind • Doing experiments with the anemometer • Measuring the circumference and area of the circle made by the anemometer	• Physics • Geometry • Maths	• Two (50-minute) classes to construct the anemometers • Two (50-minute) classes to take measurements
3. Understanding wind turbine technology	• Assessing our knowledge about wind turbines • Learning about how wind turbines work • Building a wind turbine and testing it • Grammar lesson using the new vocabulary	• Science/ Technology • Physics • Grammar	• Two (50-minute) classes to work on the wind energy videos and a virtual tour of a wind turbine • Four (50-minute) classes to build and test wind turbines. • A grammar lesson is included in this timing
4. Learning about wind	• Assessing student knowledge about wind • Putting together wind and aerodynamics experiments • Studying the global wind map and wind types • The history of wind • Studying the respiratory system	• Science/ Technology • Physics • Geography • History	• Three (50-minute) classes for wind and experiments • Three (50-minute) classes to look at the global wind map and wind types • Three (50-minute) classes to study the history of wind

MODULE 1

LEARNING ABOUT ENERGY

OVERVIEW

This is an introduction to the definition of energy, renewable energy sources and wind energy in particular. By carrying out a research assignment, students will be able to identify the differences between the various types of energy sources. By watching and reflecting on free video resources, students can learn about different aspects of wind energy, such as permitting procedures, costs, and environmental aspects.

GRADES

5-6th Primary (10-12 yo)

TIME

- One (50-minute) class to define energy
- 5 days to research energy sources at home
- Two (50-minute) classes to learn about different aspects of wind energy

SUBJECTS

- Physics
- Geography
- History

LEARNING OBJECTIVES

At the end of this module, students will gain the following knowledge and competences:

Knowledge

- Understanding various types and sources of energy
- Key considerations for wind energy: administrative and permitting procedures; economic and environmental aspects

Competences

- To classify information by groups of definitions
- To select relevant information from a written document and transcribe it into their own words
- To organise information in a written document
- To present mental images/representations in the form of drawings and text
- To take down information from a video documentary in the form of drawings
- To take notes in the form of key words while watching a video

LESSON PLAN

MATERIALS

YouTube videos about: offshore wind turbines, administrative and permitting procedures; economic and environmental aspects of wind energy.

METHOD

PART I LEARNING ABOUT ENERGY

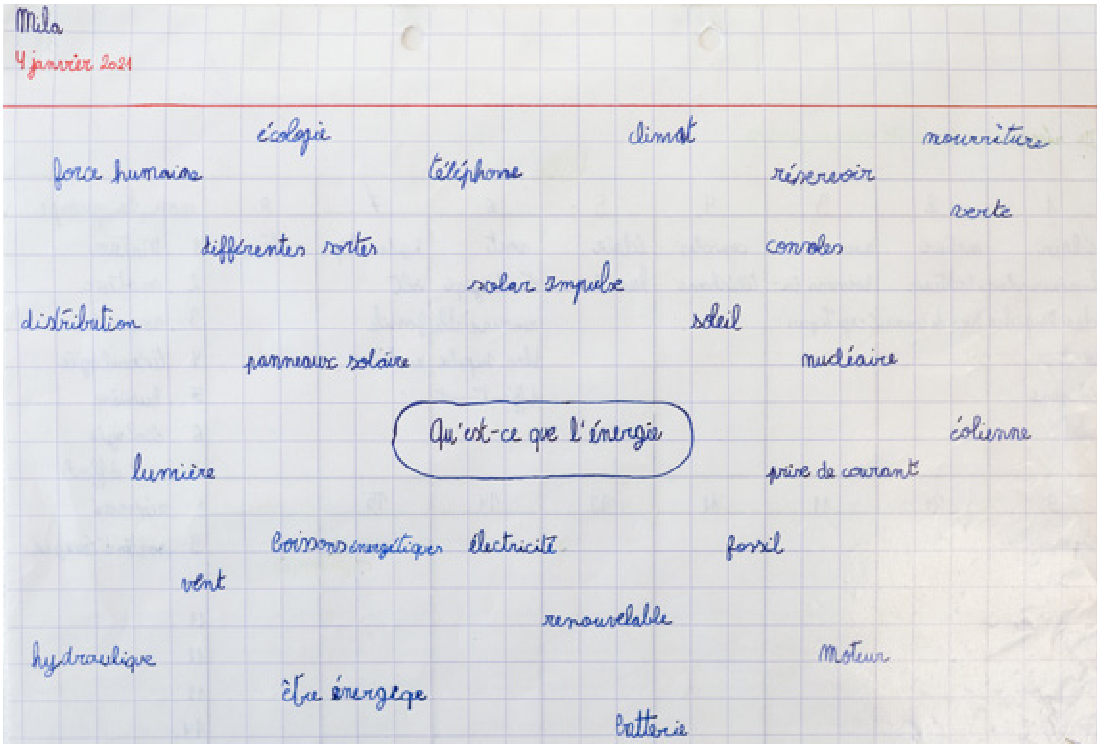
STEP 1

Introducing energy

- In the classroom, each student thinks of a few words that come to mind when they hear the word "energy"
- The teacher writes these words on the whiteboard, in no specific order
- The students copy all the words from the whiteboard into their notebook

FIG. 4

In this example, the words students came up with when thinking about energy: ecology, climate, food, human strength, telephone, reservoir, green, different types, consoles, distribution, sun, solar panels, nuclear, light, socket, wind turbine, energy drinks, electricity, fossil, wind, renewable, engine, to be energetic, battery.



STEP 2
Defining energy

The students and the teacher try to define energy and summarise their conclusions as follows:

- Energy is invisible but we can see the reaction it provokes
- We need energy to make things work
- Energy can change form

STEP 3
Energy types

The teacher gives an overview of the two types of energy: kinetic and potential (table 2). Based on this discussion, the students work in pairs to classify energy in the table below, using the words they have copied into their notebooks in step 1.

TABLE 2

KINETIC ENERGY	POTENTIAL ENERGY
Mechanical energy: makes an object move	**Chemical energy:** comes from molecules
Electrical energy: comes from an electric charge	**Nuclear energy:** stored in the nuclei of atoms
Thermal energy: based on heat	

STEP 4
Energy sources

The teacher discusses the meaning of renewable energy and fossil fuels with the students. Together, they make the following table using the words added to the whiteboard in step 1.

TABLE 3

RENEWABLE ENERGY	FOSSIL FUELS
Wind energy	Gas
Solar energy	Coal
Hydro energy	Oil

STEP 5
Researching energy sources

Each student selects one type of energy and carries out a research assignment at home over the course of the week, in which he/she summarises these three main elements on a single poster:

- Where does the energy come from?
- Is it renewable or not?
- What are the advantages and disadvantages of this type of energy?

STEP 6
Presenting the research work

- Each student presents his/her poster to the rest of the class
- A copy of each poster is distributed to all the students, so they have a summary of all the other types of energy to learn from

FIG. 5
Student poster comparing onshore wind turbines with offshore wind turbines, which states that offshore wind turbines are smaller than onshore turbines. In reality the reverse is true.

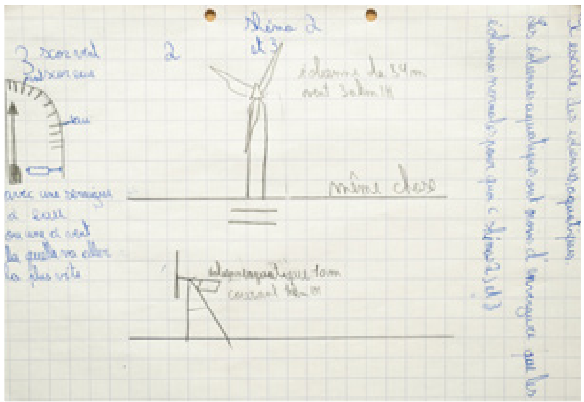
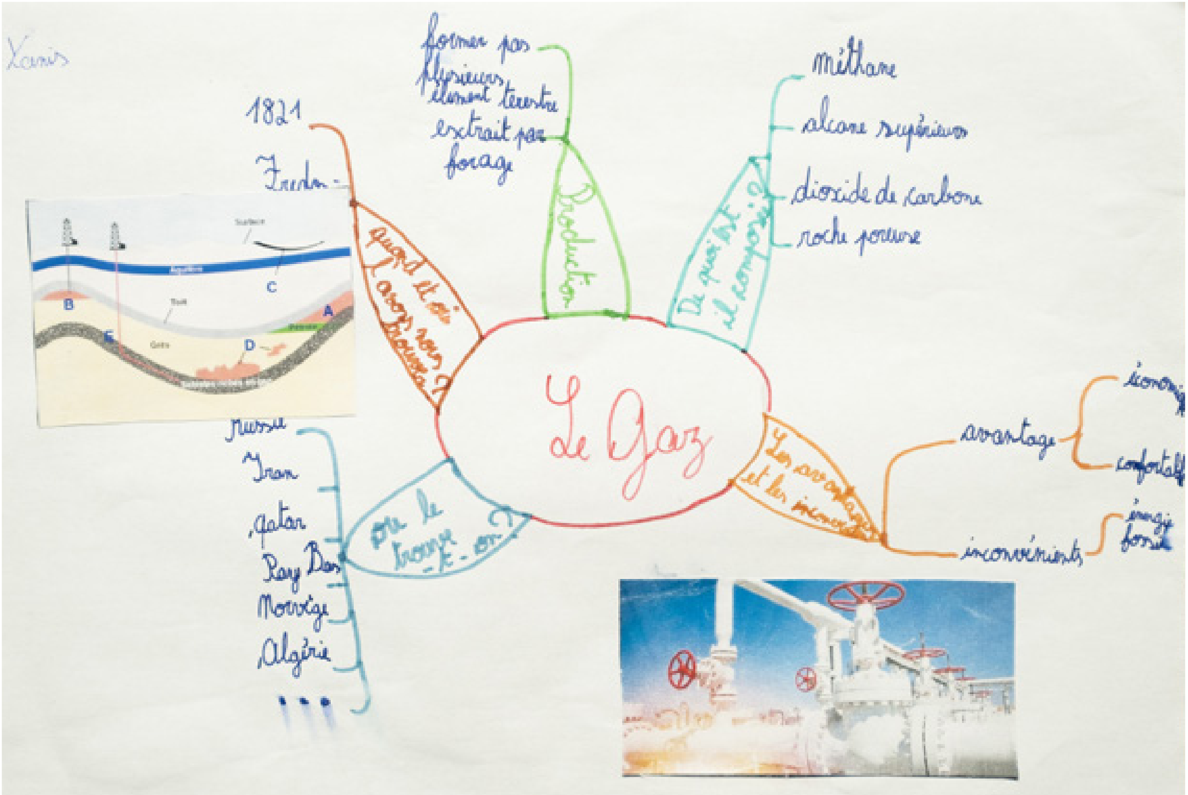


FIG. 6

Student poster on gas: where is it produced; when was it discovered for the first time; how is it produced; what is it made of; advantages and disadvantages of gas.



PART II LEARNING ABOUT DIFFERENT ASPECTS OF WIND ENERGY

- The teacher picks a number of videos from YouTube which deal with different aspects of wind energy: administrative and permitting procedures; the economic and environmental aspects of wind energy.

- Students are divided into four groups. Each group watches a different video about a particular aspect of wind energy (they are in French but they are only meant to give you a broad outline):

  › ***Group 1: How offshore wind turbines work***
  https://www.youtube.com/watch?v=iSfeRPa2EuU

  › ***Group 2: Permitting regulations and views on the impact of wind turbines on the landscape***
  https://www.youtube.com/watch?v=LG40IrxYnqs

  › ***Group 3: The cost of wind energy***
  https://www.youtube.com watch?v=0nWM2Wj3YYM

  › ***Group 4: Is wind the energy of the future***
  https://www.youtube.com/watch?v=7tvX4OJd8Nc

- Each group puts together a poster in the classroom based on what they have learnt about a specific aspect of wind energy and gives a presentation to the rest of the class.

FIG. 7

Student poster about the cost of wind energy: how much does it cost compared to nuclear energy? The evolution of wind energy prices; and the competitiveness of wind energy prices.

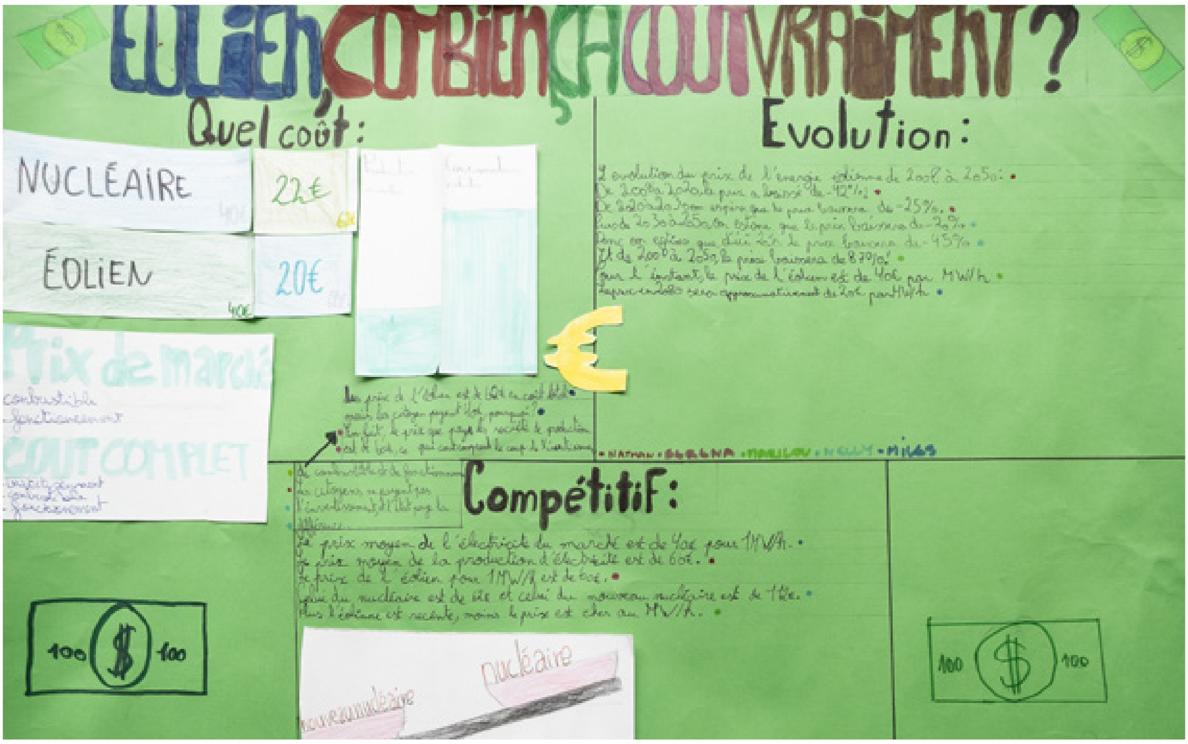


FIG. 8

Student poster on the energy of the future: or wind being the energy of the future, it requires new wind farms to be built, including offshore, and new and more efficient wind turbines and energy storage.

MODULE 2

CONSTRUCTING AN ANEMOMETER AND TAKING MEASUREMENTS

OVERVIEW

Students can learn how to measure wind speed by building a simple cup anemometer. A cup anemometer like the one below is used to measure wind speed. The cup anemometer has a vertical axis and three cups that move with the wind. A sensor keeps track of how many spins per minute the cup anemometer makes. A computer uses that information to estimate how fast the wind is blowing.

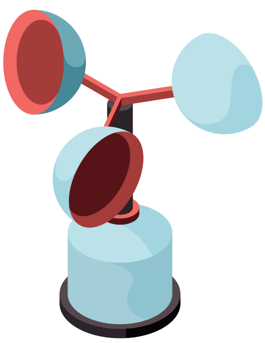
A wind turbine can only work if it knows how fast the wind is blowing, and the faster the wind blows the more electricity the wind turbine produces. That’s why it needs to measure the speed of the wind and for this it needs to be equipped with an anemometer.

Imagine a wind turbine producing electricity, and the wind speed is 5 metres per second. Imagine that the wind speed doubles, from 5 to 10 metres per second. With the new wind speed, the wind turbine will generate eight times as much electricity as before.

GRADES

5-6th Primary (10-12 yo)

FIG. 9
Anemometer



TIME

- Two (50-minute) classes to build the anemometers
- Two (50-minute) classes to take measurements

SUBJECTS

- Physics
- Geometry
- Maths

LEARNING OBJECTIVES

At the end of this module, students will have acquired the following knowledge and competences:

Knowledge

- How to measure length
- Velocity -> Wind velocity
- The circumference and area of the circle: learning new formulae
- Discovering and understanding the concept of Pi (π)

Competences

- Planning and designing a project in 3D
- Comparing results and organising them in a double entry table
- Discovering and using the scientific method
- Thinking rationally when faced with a challenge and identifying possible solutions using available evidence
- Presenting this reasoning to the group

LESSON PLAN

MATERIALS

- Wooden shafts
- Wooden arms
- Empty yoghurt pots
- A mechanism to make the arms turn

METHOD

On a windy day, ask the students how can they measure the speed of the wind?
Answer -> An anemometer!

STEP 1
Constructing an anemometer

- In teams of three, students come up with a plan to build an anemometer, by answering these three questions:
  - How many arms does it need?
  - What type of cup can be used?
  - How big is each part of the anemometer?
- Each team makes a scale diagram of their anemometer (Fig 10)
- Based on the drawing, each team builds their anemometer using wood for the vertical shaft and the arms, yoghurt pots for the cups and a mechanism to make the arms turn

TABLE 4
Examples of sizes of the anemometers each team can build

TEAM	Size of the base	Size of the vertical shaft	Size of the horizontal arms
1	9 x 9 cm	20 cm high	15 cm long
2	15 x 15 cm	40 cm high	15 cm long
3	12 x 12 cm	30 cm high	14 cm long
4	18 x 18 cm	15 cm high	15 cm long
5	20 x 20 cm	40 cm high	10 cm long
6	15 x 15 cm	30 cm high	15 cm long
7	20 x 20 cm	25 cm high	20 cm long

FIG. 10
Example scale diagram with the different components: base, vertical shaft, horizontal arms.

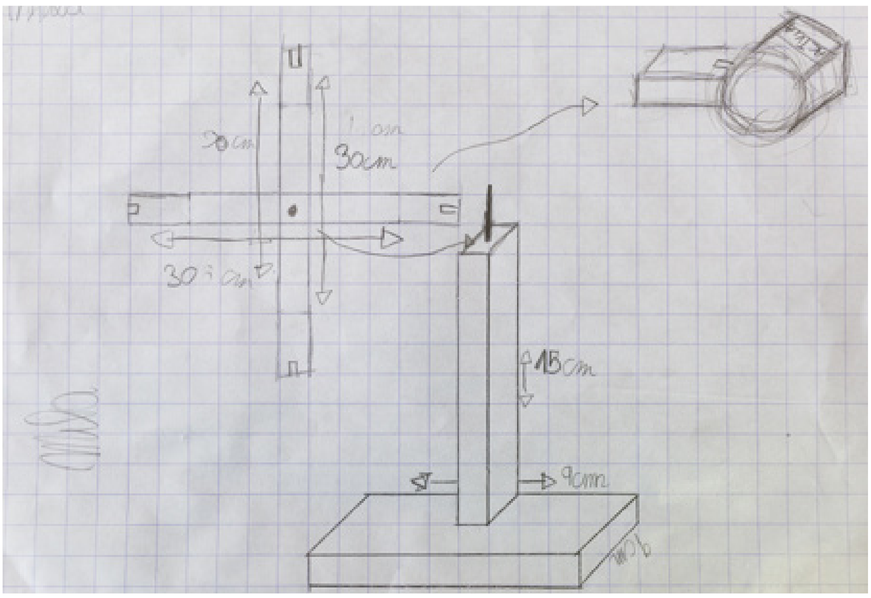


FIG. 11
Students place the horizontal arms on the vertical shaft of the anemometer

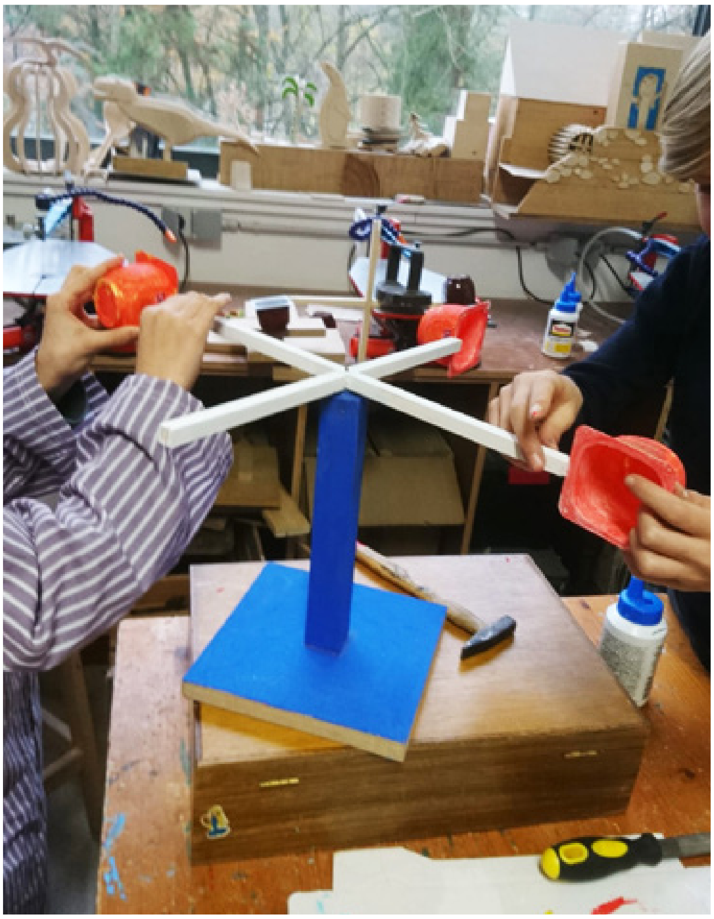


FIG. 12
Students attach the cups (empty yoghurt pots) to the horizontal arms of the anemometer.

STEP 2

Using an anemometer to measure wind

Once the anemometers are built, they need to be tested.

- On a windy day, in a well-ventilated area of the school playground, each team counts the number of spins their cups make over a 30 second period, by placing a coloured marker on one of the cups to help with the counting

- A member of the team records the number of spins on a table and compares the results with the other teams

- The more spins, the faster the wind is blowing and the higher the wind speed!

STEP 3

Doing experiments with the anemometer

- As a group, the students should discuss why the number of recorded spins is different from one team to another

Do sizes of the anemometer arms have an influence on the number of spins?

- To answer the question, students should carry out the following experiment in the classroom:

Material:

- 3 anemometers of different sizes for the base, the vertical shaft and arms made by the students (see table above)
- 1 fan
- 1 chronometer

Hypothesis:

The students put forward their own hypothesis: the anemometer that has the longest arms will rotate the fastest.

Experiment:

- The students turn on the fan facing the anemometer
- Try different fan speeds and distances until the anemometer starts spinning
- For each anemometer, students count the number of revolutions over a 30 second period
- Students notice that the anemometer that spins the most is the one with the shortest arm length

Conclusions:

The class arrives at the same conclusions:
- The shorter the arms of the anemometer, the faster the anemometer spins
- The longer the arms, the fewer spins the anemometer makes
- The cups of the anemometer move in a circle
- The "length of the circle" made by the rotation of the cups is shorter when the blades are shorter

This comparison does not take into account the size of the cups. The influence of the size of the cups on the number of spins could be part of the discussion with the students.

STEP 4

Measuring the circumference and area of the circle made by the anemometer

Up until now, the students saw that the anemometer cups moved in a circle.

Maths challenge:

- Ask the students to solve this challenge individually:

How to measure the circumference of the circle their anemometer makes when it rotates?

Measurements:

- To measure the circumference, students are free to use the materials they want. Ideally, they could use a piece of string to cover the length of their circle
- The students write down the ''length'' of their circle = the **circumference (C)**
- The students also measure the **diameter (D)** and the **radius (r)** of their circle and write them dow.

Comparison and observation:

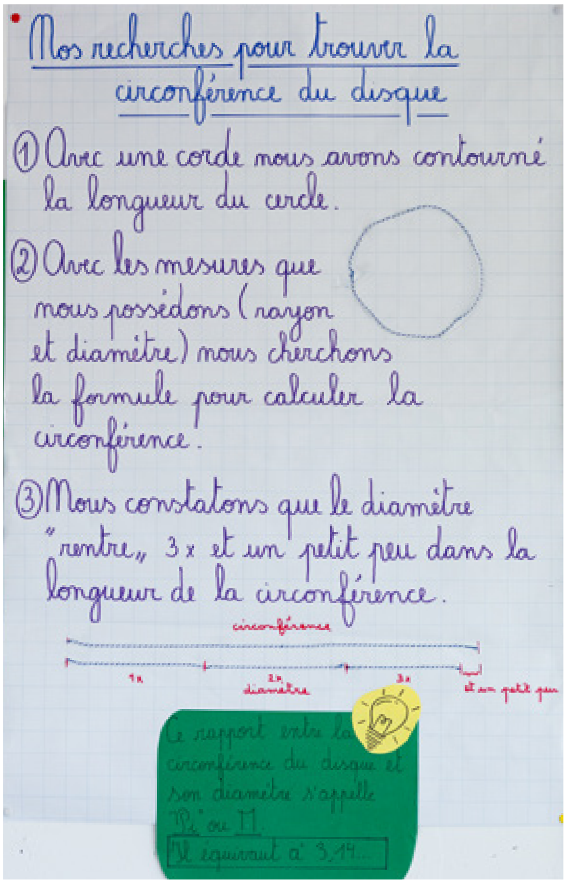
- Ask the students to compare the **diameter** of their circle with the circumference of their circle
- Students will observe that the circumference adds up to slightly more than **3 times** the diameter of the circle

Conclusions:

The teacher introduces the number Pi (π) and the formulae for calculating circumference and area:

- The ratio of the circumference of the circle to its diameter is called **Pi (π)**
- **Pi (π)** equals **3.14**
- The formula for calculating the circumference of the circle is **C = π x D**
- The formula for calculating the area of the circle is **A = π x r x r**

FIG. 13
Students take down their conclusions in a notebook



1. We put a string around the length of the circle
2. With the measurements of the radius and the diameter, we came up with the formulae for calculating the circumference of the circle made by the anemometer arms;
3. We observed that the circumference adds up to slightly more than 3 times the diameter of the circle.

MODULE 3

UNDERSTANDING WIND TURBINE TECHNOLOGY

OVERVIEW

By watching free video resources, students can learn more about the different components of a wind turbine and how they work. They will build their own wind turbines and test them to calculate the time it takes for a turbine to lift a 20g weight.

GRADES

- 5-6th Primary (10-12 yo)

TIME

- Two (50-minute) classes to work on the wind energy videos and a virtual tour of a wind turbine
- Four (50-minute) classes to build and test wind turbines

SUBJECTS

- Science/Technology
- Physics
- Grammar

LEARNING OBJECTIVES

At the end of this module, students will have acquired the following knowledge and competences:

Knowledge

- How a wind turbine works, and its different components
- Understand the lift and drag forces
- Understand the generation of energy from rotations

Competences

- To present mental images/representations in the form of drawings and text
- To draw information from a video documentary
- To take notes in the form of key words while watching a video
- To build a 3D object using recycled material

LESSON PLAN

MATERIALS

To build wind turbines in the classroom you will need:

- Small-scale wind turbines between 20 and 50 cm in height (e.g. Vestas or Siemens Gamesa)
- Plastic bottles measuring 1.5 or 2 litres + cups
- Sand to fill the plastic bottles to help stabilise them
- Cardboard or paper to make the blades
- Wooden sticks to hold the blades in place
- A cork to help fix the blades
- Sticky tape and instant glue
- Small generators equipped with a small LED bulb
- 20g weights
- A string to attach the 20g weight
- A fan

See the step-by-step guide to building a wind turbine with recycled material in Support Material for the Teacher

METHOD

STEP 1
Constructing an anemometer

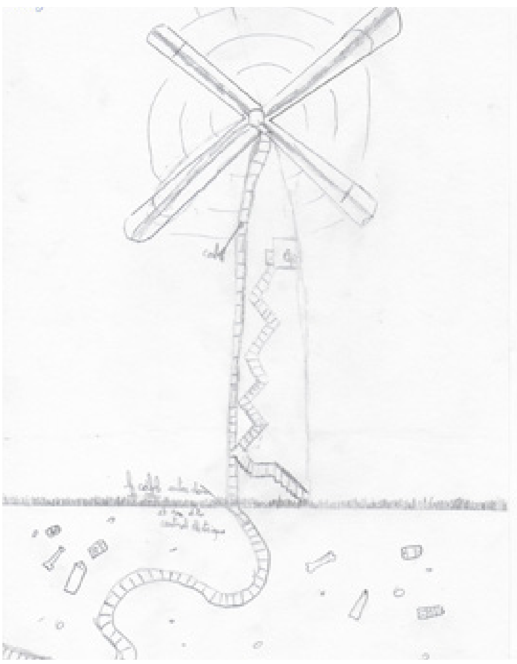
- Each student gives a written answer to the following three questions, presenting their thoughts (representations) about wind turbines and wind energy:
  - What do I know about wind turbines?
  - What would I like to learn about them?
  - Why is this topic relevant?

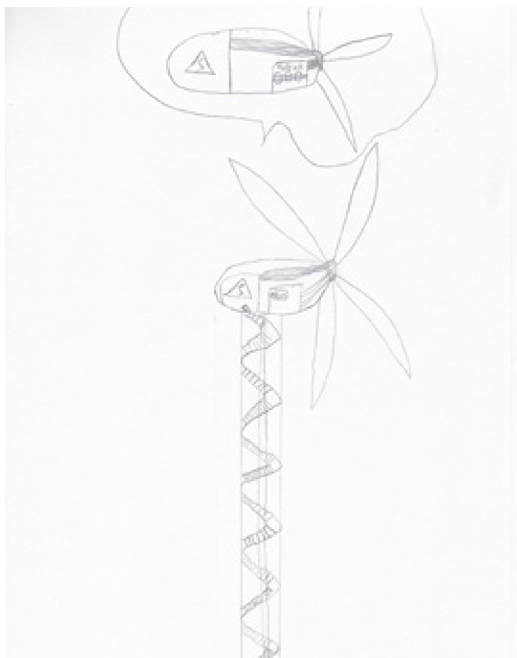
- Each student makes a diagram of a wind turbine and how it works based on what they already know/ imagine (fig. 14)

- Each student explains their diagram in the form of text

- This will serve as a starting point for the upcoming activities, when discussing how a wind turbine works

FIG. 14 & 15





Example of a student summary

Exterior of a wind turbine

1. BLADES
- Generally **three**
- **Aerodynamic** shape

2. NACELLE
- **Wind vane:** indicates wind direction
- **Anemometer:** measures wind strength
- **Lightning protection:** protects the wind turbine from lightning strikes

3. TOWER
- **80** metres tall

Interior of a wind turbine

4. NACELLE
- **Generator:** transforms wind energy into electricity
- **Yaw drive:** helps the blades to face the wind
- **Gearbox:** increases the rotation of the main shaft when there is not enough wind
- **Rotor axis**
- **Emergency brake:** stops the turbine when there is too much wind

Size of a modern wind turbine:

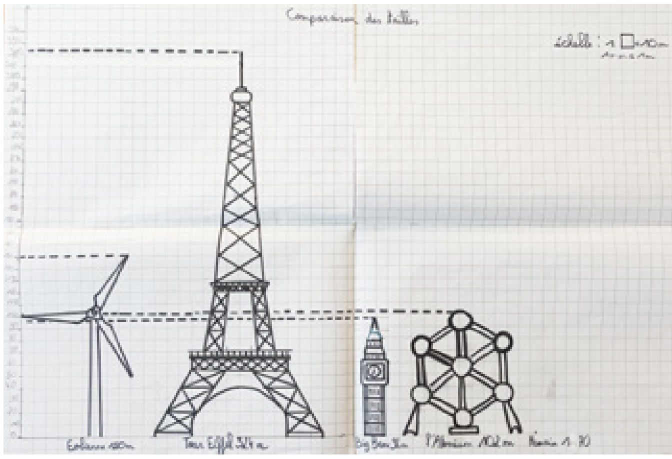


FIG. 16
Students calculate the height of a wind turbine
Scale: 1 cm = 10 m.

Weight of a modern wind turbine:

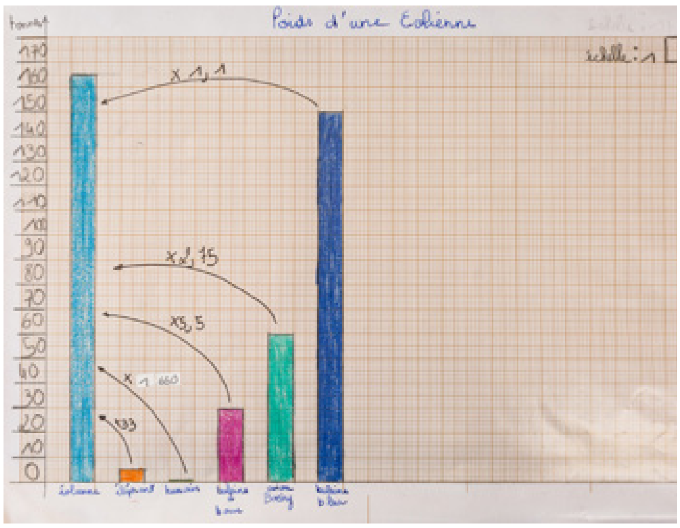


FIG. 17
Students calculate the weight of a wind turbine compared to an elephant, a human, a humpback whale, a Boeing plane and a blue whale. Scale: 1 cm = 10 tonnes.

STEP 2
Learning about how wind turbines work

- To start, all students in the class watch a video together to learn more about the different components of a wind turbine and how wind turbines work https://www.youtube.com/watch?v=gHUJqTT3THU&

- Students take notes while watching the video

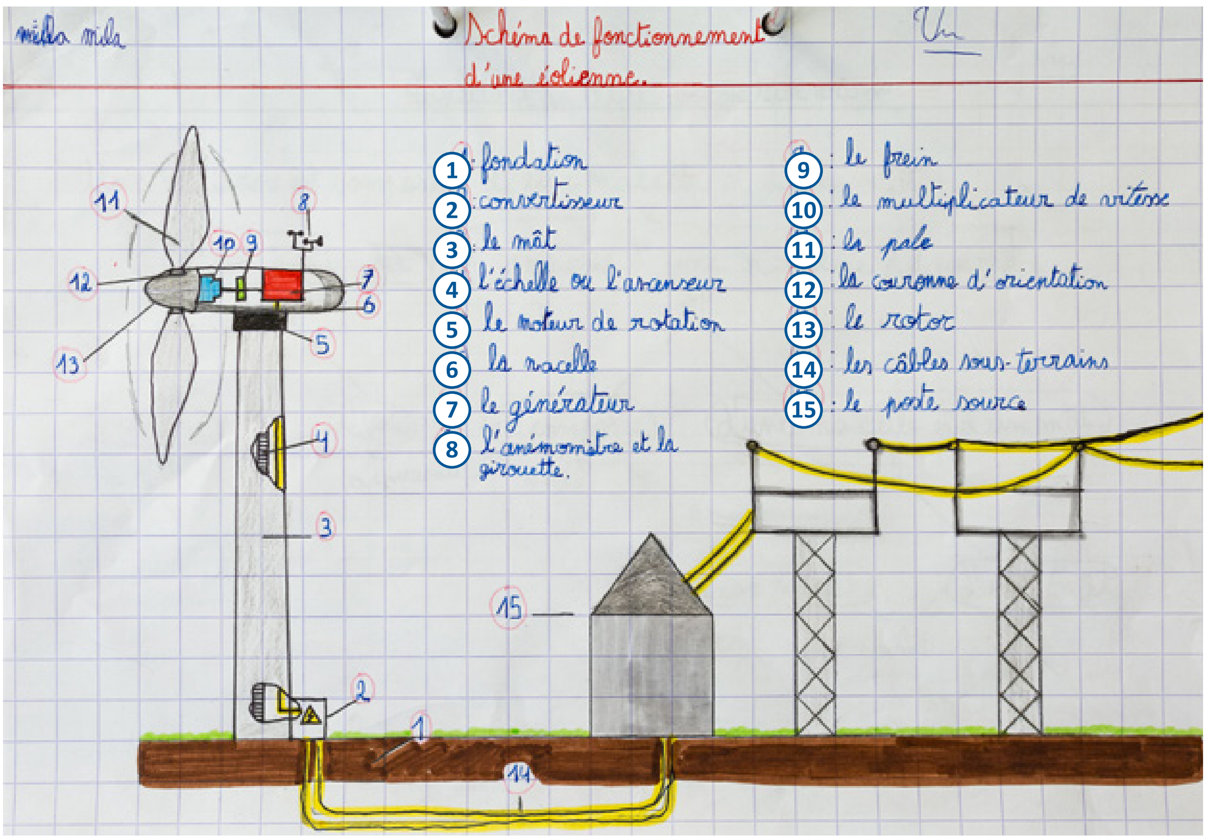
- They then study real small-scale wind turbines (20 to 50 cm tall, such as Vestas or Siemens Gamesa)

- With all this, they can make a summary describing (see previous page):
  - The exterior of a wind turbine
  - The interior of a wind turbine
  - The size of a modern wind turbine compared to other buildings they know.
  - The weight of a modern wind turbine

STEP 3
Making a final diagram of a wind turbine

Based on the summary of the notes from steps 1 and 2 students should work together on a diagram representing a wind turbine and its different components, like the example below:

FIG. 18



1. Foundation
2. Connection to the electricity grid
3. Tower
4. Access ladder or lift
5. Wind orientation control (Yaw control)
6. Nacelle
7. Generator
8. Anemometer and wind vane
9. Brake
10. Gearbox
11. Rotor blade
12. Blade pitch control
13. Rotor hub
14. Underground cables
15. Substation

STEP 4
Building a wind turbine

- To successfully build a wind turbine in the classroom, students should aim to complete the following challenge:

    - **Build a wind turbine with recycled material that can lift a 20g counterweight as quickly as possible** (using the step-by-step guide in the section Support Material For The Teacher below)

    - **Explanation of the challenge:** The spin of a wind turbine rotor comes from the aerodynamic interaction between the blades and the wind. During this interaction two forces are created: the lift force, which triggers the rotation, and the drag force which acts against the blade movement in the opposite direction, trying to decelerate it. The performance of a wind turbine with a given diameter (limited in this challenge to 30 cm) depends on the blade shape and the number of blades being used. To see which performs best, students do experiments with different blade geometries and different blade ranges

- Students are divided into groups of 4. They then select the material they will need and think about how to go about building their wind turbines. They should pay attention to the **orientation** of the blades, their **shape**, **size** and **material**

- Fill the bottles with sand to make them more stable, then attach the generator. Build wedges to link it to the bottle

- When the wind turbines are built, each group tests it using a fan to generate wind

Instructions on shape and orientation of the blades:

Different types of blades can be used in the class:

FIG. 19

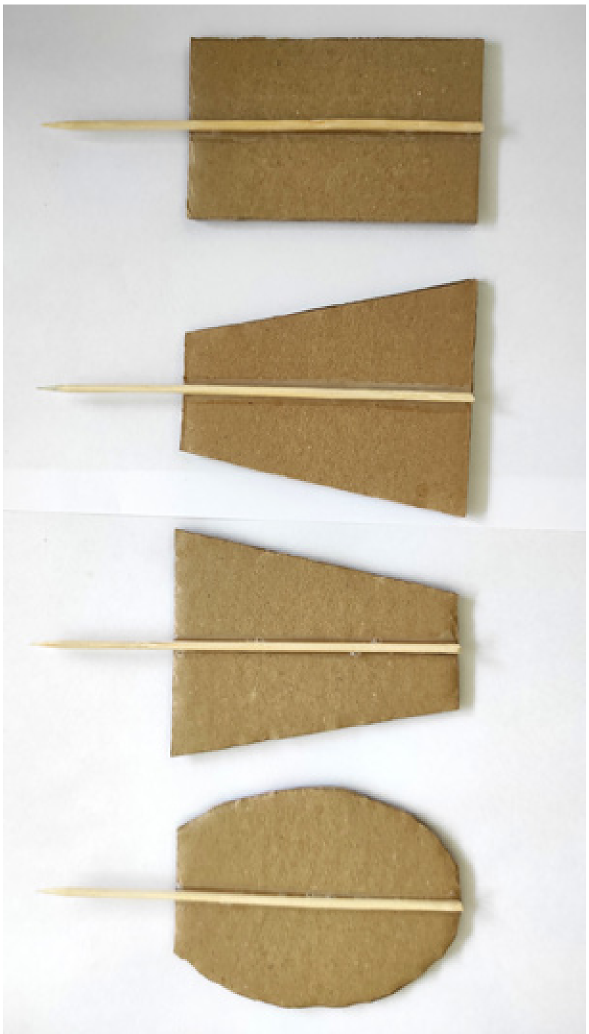


FIG. 20

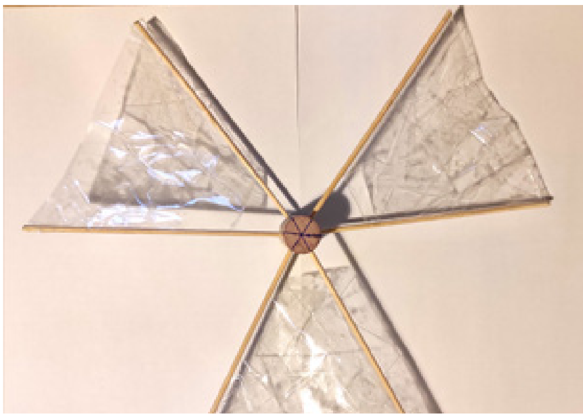


FIG. 21
The blades are set onto the hub so that they face the flow with maximum surface exposure. In this case the rotor will offer strong resistance. No lift force is created, and the rotor can't spin

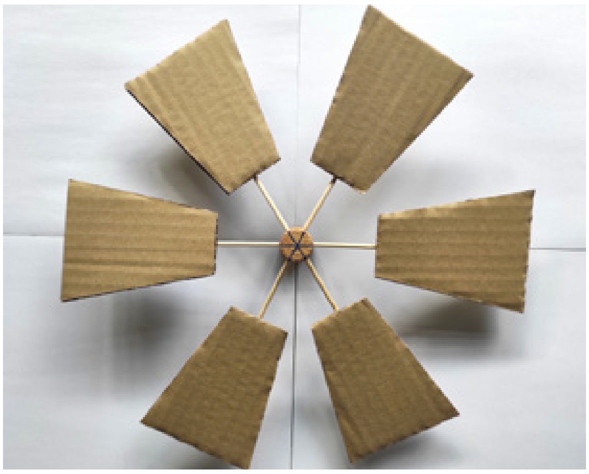


FIG. 22
The flow of the wind is axial (the wind blows from our location towards the rotor), the entire airflow will pass through the blades with almost no interaction at all. Once again, it won't rotate.

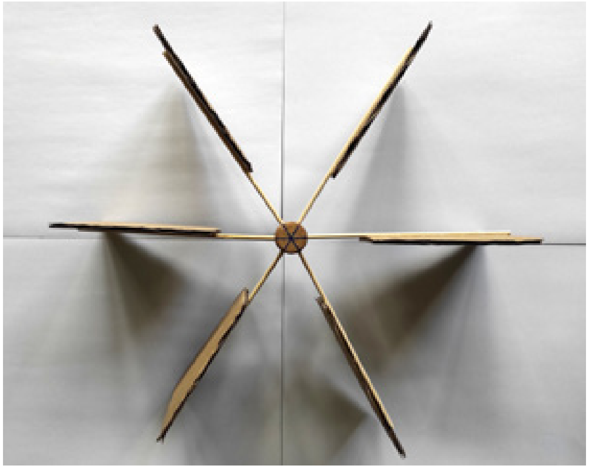
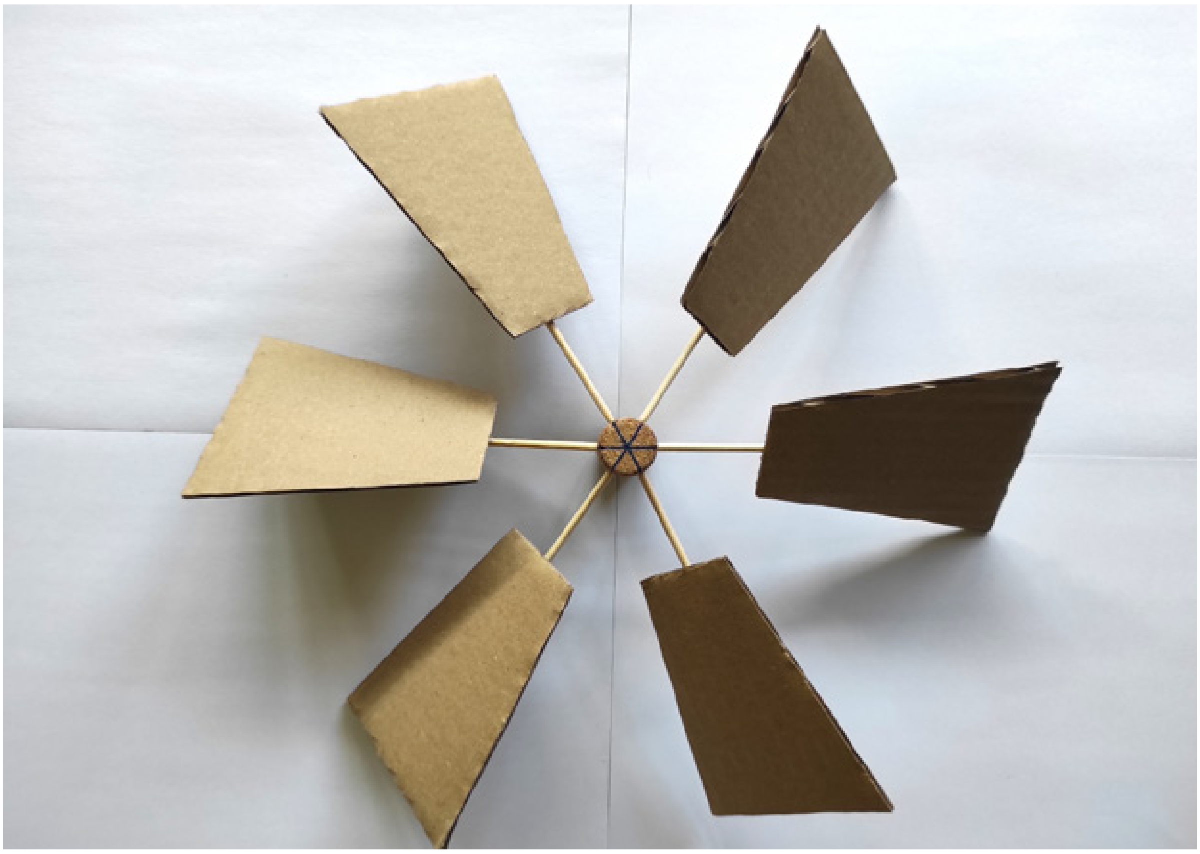
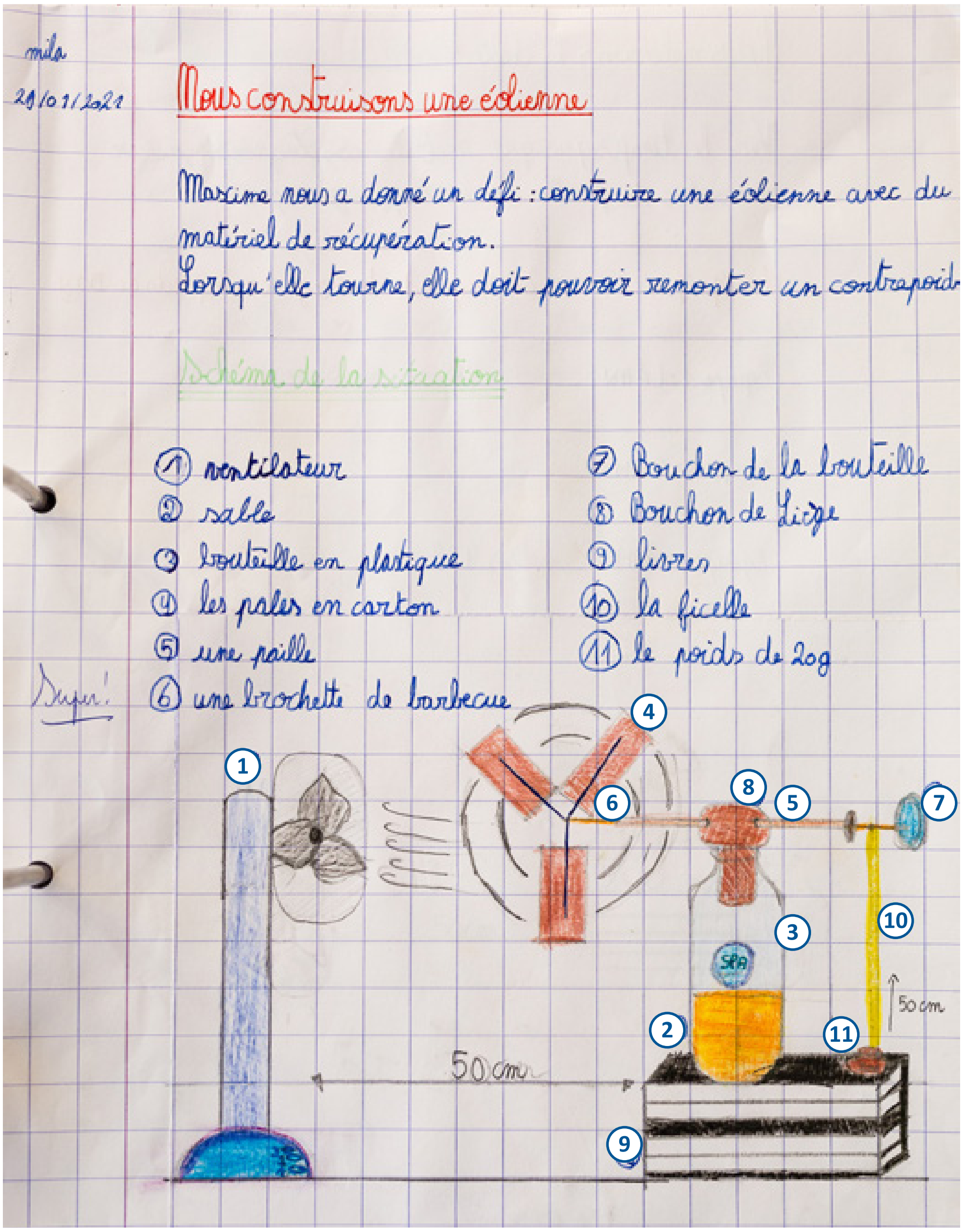


FIG. 23
When the blades are rotated at an angle of 45° degrees, there is a strong interaction between the oncoming wind and the blades. The flow passing through the blades creates a lift force that spins the rotor. We can also set angles other than 45° degrees to find the best angle (pitch) for our rotor design.



Building the wind turbines:

FIG. 24
Student drawing explaining the construction of the wind turbine and the challenge exercise.



1. Fan
2. Sand
3. Plastic bottle
4. Cardboard blades
5. Drinking straw
6. Barbecue skewer
7. Bottle cap
8. Cork
9. Books
10. String
11. 20g weight.

FIG. 25
Wind turbines built by the students

FIG. 26
Student with her wind turbine.

FIG. 27
Wind turbine made by a student at a scale of 1:100

The challenge;

When everyone is ready, the competition can get underway, one group at a time. The students should record the time it takes for their wind turbine to lift a 20g weight, using a table (see below).

TABLE 5

GROUP	TIME (SECONDS)
1	5.40
2	3.42
3	7.73
4	4.04

This challenge can also be carried out using a heavier counterweight.

STEP 5
Grammar lesson using the course vocabulary

To make the curriculum easier to understand, the teacher can use the subject of wind turbines indirectly to teach grammar. This could mean using sentences from the discussion as the basis/material for a grammar lesson.

Examples of sentences:

- On Tuesday, our class saw a video on wind turbines
- A wind turbine is made up of a nacelle and a tower


SPEED
SOME
VUE
990

MODULE 4

LEARNING ABOUT WIND

OVERVIEW

By conducting simple experiments, students can understand how wind is formed and what makes the blades of a wind turbine spin. They can learn about different types of wind through global wind maps. A research assignment will allow students to learn about the history of wind, from sailing ships to modern wind turbines. We use our respiratory function to play wind instruments, so how does our respiratory system work?

GRADES

5-6th Primary (10-12 yo)

TIME

- Three (50-minute) classes for wind and experiments
- Three (50-minute) classes looking at the global wind map and wind types
- Three (50-minute) classes looking at the history of wind

SUBJECTS

- Science/Technology
- Physics
- Geography
- History

LEARNING OBJECTIVES

At the end of this module, students will have acquired the following knowledge and competences:

Knowledge

- What is wind? How is it created?
- Aerodynamics: general principles
- Wind types around the world
- Historical periods: ways of life and beliefs of different civilisations
- The respiratory system: overall functioning + diagram

Competences

- Work on the scientific method
- Formulate a hypothesis and verify it
- Study a map of the world and find relevant clues relevant to the theme
- Classify these clues in groups
- Memorise information and be able to rewrite it in their own words in a synthesised way
- Research historical documents and find relevant information
- Observe a dissection and make an observational drawing
- Write an account of the dissection

LESSON PLAN

MATERIALS

- Glass filled with water
- Card
- Balloon
- Plastic bottle
- Hot water
- Cold water (ice)

METHOD

STEP 1
Assessing student knowledge about wind

Students start by answering the question:

What do I know about wind?

- Each student puts his/her thoughts about wind (as representations) down in a drawing and a text. An example of the text: ''There is more wind at sea than on land''

- Each student explains their drawing and text to the rest of the class

- This will serve as a starting point for the upcoming activities, when discussing wind

STEP 2
Putting together wind and aerodynamics experiments

PART I WIND

Based on the students' ideas, the next two experiments will try to build on their knowledge of wind. The experiments are carried out according to the scientific approach.

EXPERIMENT 1

Air pressure, also called atmospheric pressure

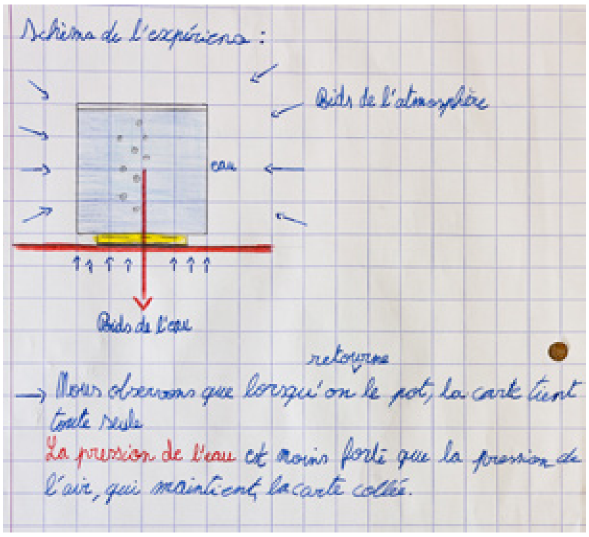
A glass is filled to the brim with water and covered with a card. The glass is slowly turned upside-down. What will happen?

Hypothesis:
Students make their own hypotheses:
- Small air bubbles will rise to the surface
- The paper will get absorbed and won't hold in place
- The paper will hold

Observation:
Students observe that when the glass of water is turned upside-down, the card sticks to the cup on its own and doesn't fall.

Interpretation:
The teacher explains that the pressure of the water is weaker than the pressure of the air. It is the pressure of the air, also called atmospheric pressure, that keeps the card sticking to the glass.

FIG. 28
Student notebook. Experiment 1 on air pressure.



EXPERIMENT 2

The effects of temperature differences

- Remove the cap from a bottle and pass the neck of a balloon around the neck of the bottle
- Place the bottle with the balloon in a bowl of boiling water, then in a bowl of cold water

What will happen?

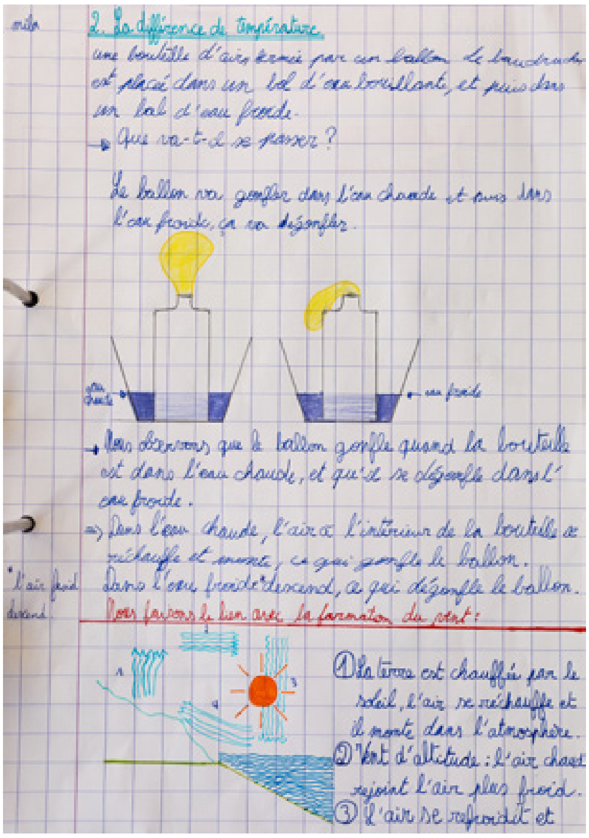
Observation:

The balloon inflates when the bottle is in hot water and deflates when the bottle is in cold water.

Interpretation:

The teacher explains that **in hot water**, the air inside the bottle warms, expands and rises, which inflates the balloon. **In cold water**, the cold air falls, deflating the balloon.

FIG. 29
Student notebook. Experiment 2 on the effects of temperature difference.

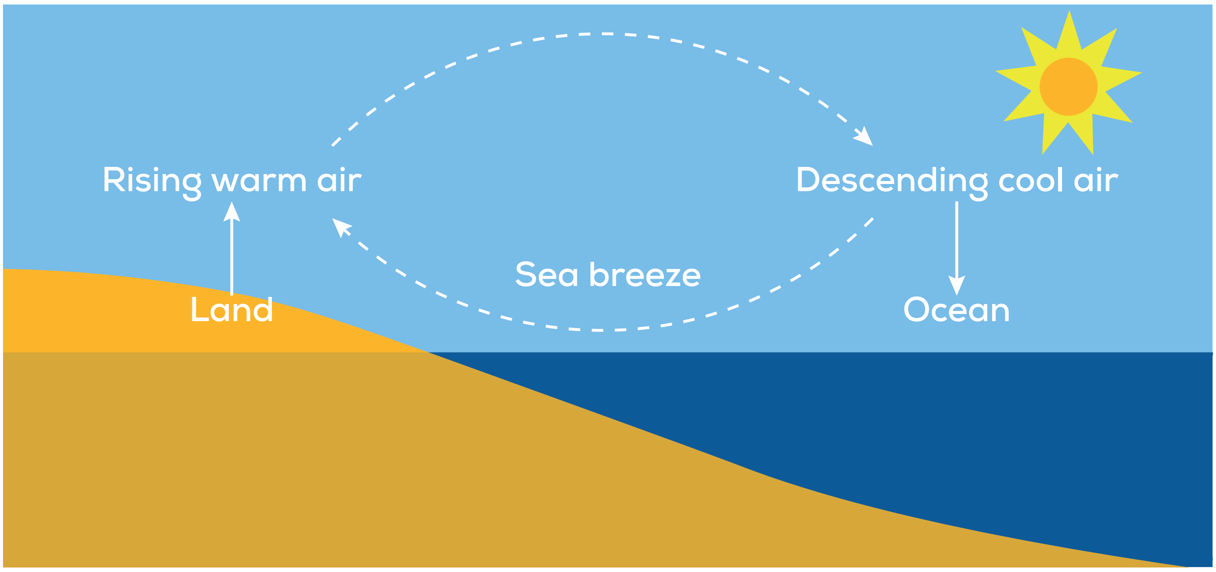


THE CONNECTION WITH WIND FORMATION

The teacher and the students discuss the results of the two experiments to try and identify how wind is created:

- The sun heats one part of the atmosphere differently to the other parts
- When the earth is heated by the sun, the air warms up, expands and rises into the atmosphere, causing pressure to drop in warm areas compared to cooler areas
- The air in cold areas cools and sinks creating high pressure
- Air always moves from high pressure to low pressure areas and this movement of air is wind (Fig. 30)

FIG. 30



PART II AERODYNAMICS

COMPETITION:

The blades in a modern wind turbine have a shape that is similar to the wings of an airplane. To understand the interaction between the wind and wind turbine blades, the teacher can set up a competition between the students to show how an airplane is able to fly:

! **In teams of two, students build a paper plane and make it fly as far as possible.**

- The competition takes place in a corridor of the school, sheltered from the wind
- The students will find that some airplanes fly farther than others
- The students measure the distance covered by their planes and put together a table to compare results

** This exercise can also be an opportunity to work on or review length measurements.*

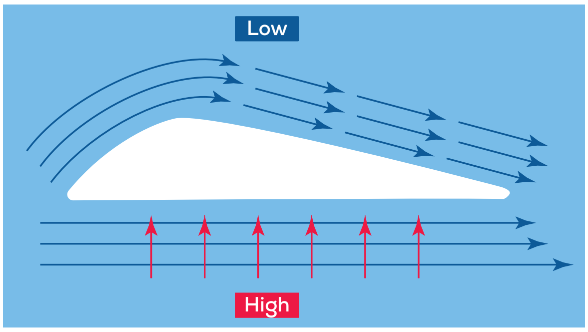
RESEARCH QUESTION:

Teacher asks the students:

? **Why do some airplanes fly farther than others?**

To answer this question, the students should try to come up with hypotheses by comparing the paper airplane with a real airplane.

FIG. 31
Cut section of wind turbine blade has one flat side and one more rounded side.



HYPOTHESES

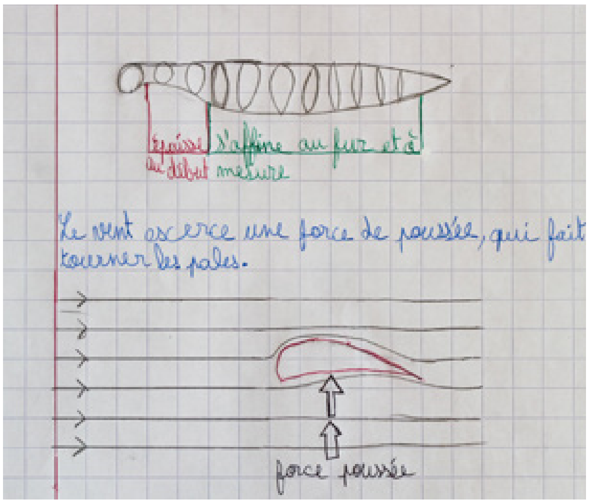
TABLE 6
Examples

PAPER AIRPLANE	REAL AIRPLANE
• Thin and light. • Pointed at the end. • The shape of the wings is important. • The wings are symmetrical.	• The wings are rounded at the top and flat at the bottom: depression. • Air pressure lifts the plane.

EXPLANATION:

- The wind in picture 31 below travelling around the longer, curved edge creates a lower pressure pocket while the wind below stays at the same pressure, creating a pressure imbalance compared with the wind above
- Wings are shaped in such a way that air flows more quickly across the top of the wing. When air travels more quickly, its pressure decreases. Thus, the pressure at the wing's top is less than the pressure at the wing's bottom. The pressure differential acts as a lifting force
- On a wind turbine, the lift on the blades drives its rotational motion, creating a torque that balances the torque at the generator

FIG. 32
Student notebook. The lifting force creates a rotational force and causes the blades to spin.



STEP 3

Studying the global wind map and wind types

- Students take a look at the global wind map e.g. the wind maps taken from January and February 2021
- They write down the names of local winds
- The teacher prepares a fact sheet for each local wind
- He/she places these fact sheets in different places along the corridor of the school
- Students summarise the fact sheets individually, in the form of a text or a mind map. To do this, they move quietly around the corridor reading the teacher's descriptions, leaving their writing sheet on the bench. They record as much information as they can and write it down on their sheet. Students can visit each fact sheet a maximum of three times

Example of a student's text summary of the local wind fact sheets:

- The **Sirocco** is a strong wind from Africa. It originates in Algeria, Morocco and Tunisia and can reach Greece, Sicily, Corsica and sometimes as far as the Alps. It can reach speeds of up to 100 km/h
- The **Harmattan** is a wind that flows across East and Northeast Africa. It carries a lot of sand which can often hinder the view of airplanes. The Harmattan is a winter wind that blows from December to January. When it blows, the days are very hot but the nights are very cool
- The **Alizé** is a regular wind that blows between the tropics. In the northern hemisphere, it blows northeastward and south of the Equator, it blows southwestward
- A **blizzard** is a snowstorm combined with strong winds. It reduces visibility to just a few metres
- **Tropical cyclones**: a cyclone is a tropical storm with thunderstorms and large cloud systems. These clouds and winds begin to circle around the eye of the cyclone, an area of calm weather. This storm moves forward and devastates everything in its path

FIG. 33
Map of well-known global winds.

STEP 4
History of wind

The students should start by asking questions about the role of wind in history:

- beliefs;
- uses of wind;
- legends;
- wind-related inventions;
- wind musical instruments...

RESEARCH ASSIGNMENT

Each team of 3 or 4 students should select a historical period or a civilisation they want to focus on for their research on wind, covering aspects such as beliefs, uses for wind, legends, inventions related to wind, etc. Examples of possible historical periods and civilisations include:

- Ancient Egypt
- Ancient Greece
- The Roman Empire
- The Vikings
- The Middle Ages
- The Modern Era

Each team creates a poster with the most important information and pictures to summarise their research findings. They can then present it to the rest of the class. The posters are then placed on the classroom timeline.

FIG. 34
Student poster on wind in Ancient Egypt. It describes:

- *Wind-related Inventions: Wind towers; windmills; sailing boats.*
- *Wind instruments used: flutes; clarinets; trumpets; oboes.*
- *Wind-related beliefs: Horus, God of wind; Amun, God of the sun and wind; Amonet, Goddess of wind; Seth, God of thunder.*
- *The Egyptians used felucca to sail on the River Nile.*

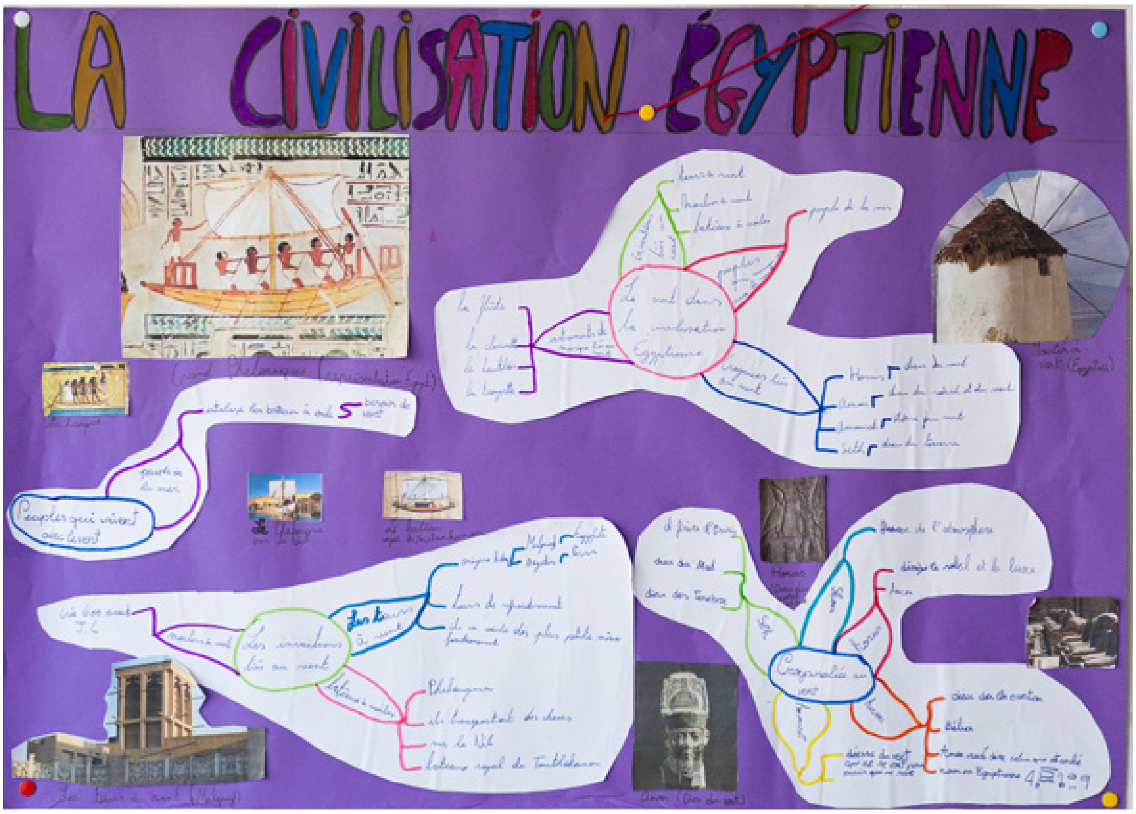


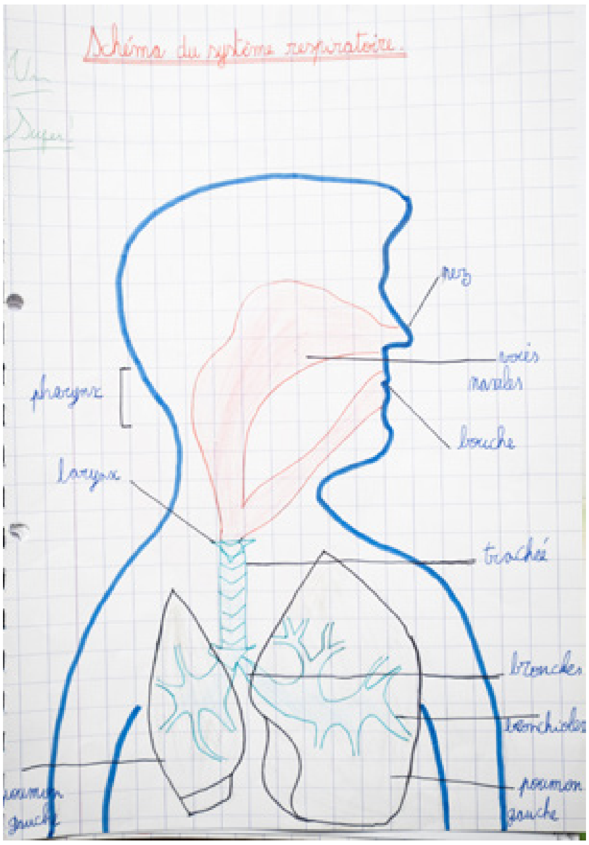
FIG. 35
Each poster is then placed along a classroom timeline.

STEP 5
Studying the respiratory system

To make the curriculum easy to understand, the teacher can use the subject of wind to teach students about the respiratory system. In their previous research assignments, the students saw examples of different wind instruments across world history. We use our respiratory system to power these wind instruments.

- Students make an initial diagram showing what they know or how they think the respiratory system works
- To back this up, they do a dissection of a pig's lung
- Each student makes a drawing of the lungs and describes it in the form of a text
- Students carry out research about the lung and the respiratory system and make their own summaries with pictures

FIG. 36
Initial representations of the respiratory system.



SUPPORT MATERIAL FOR THE TEACHER

This Toolkit offers support material for the teacher to help implement the curriculum. It was prepared by wind energy experts and is meant to inform the teacher about the subject area of each module. This will help the teacher to plan out his/her lesson and to help them pass on this knowledge to the students. Activities in this material should make use of recycled and affordable material.

The support material contains the following and can be downloaded here

Theoretical aspects

- The concept of energy, its types and forms
- The concept of aerodynamics, how it explains the shape of wind turbine blades and their interaction with wind
- The concept of air and atmospheric pressure
- The European Wind Atlas
- How do we measure wind?
- Basic components of a wind turbine

Classroom activities & experiments

- Forms of energy
- Energy transformation
- Atmospheric pressure and wind formation

Classroom discussions

- Renewable versus non-renewable sources of energy; their advantages and disadvantages

YouTube videos

- Virtual tours inside and outside a wind turbine

Step-by-step guides and instructions

- Building a cup anemometer and taking measurements
- Building a wind turbine and making it spin
- Making a wind vane and finding the wind direction

To find out more you can use the following resources:

School resources:

- Wind with Miller
- Alliant Energy Kids
- Energy student resources
- NEED Curriculum Resources
- Wind for Schools

WindEurope LearnWind free resources:

- **Let the wind blow** book & video
  Explains climate change & wind energy

- **When I Grow up** book
  Inspires young adults to consider a career in clean energy

- **Wind Energy Basics** animation
  Teaches users about wind energy technology

- **Offshore Wind 4 Kids** workshops
  Demonstrates how offshore wind turbines work

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If you are interested in distributing or translating this Toolkit, contact yamina.guidoum@windeurope.org

If you are a teacher implementing this plan in your school, we would be happy to receive your feedback at yamina.guidoum@windeurope.org.

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