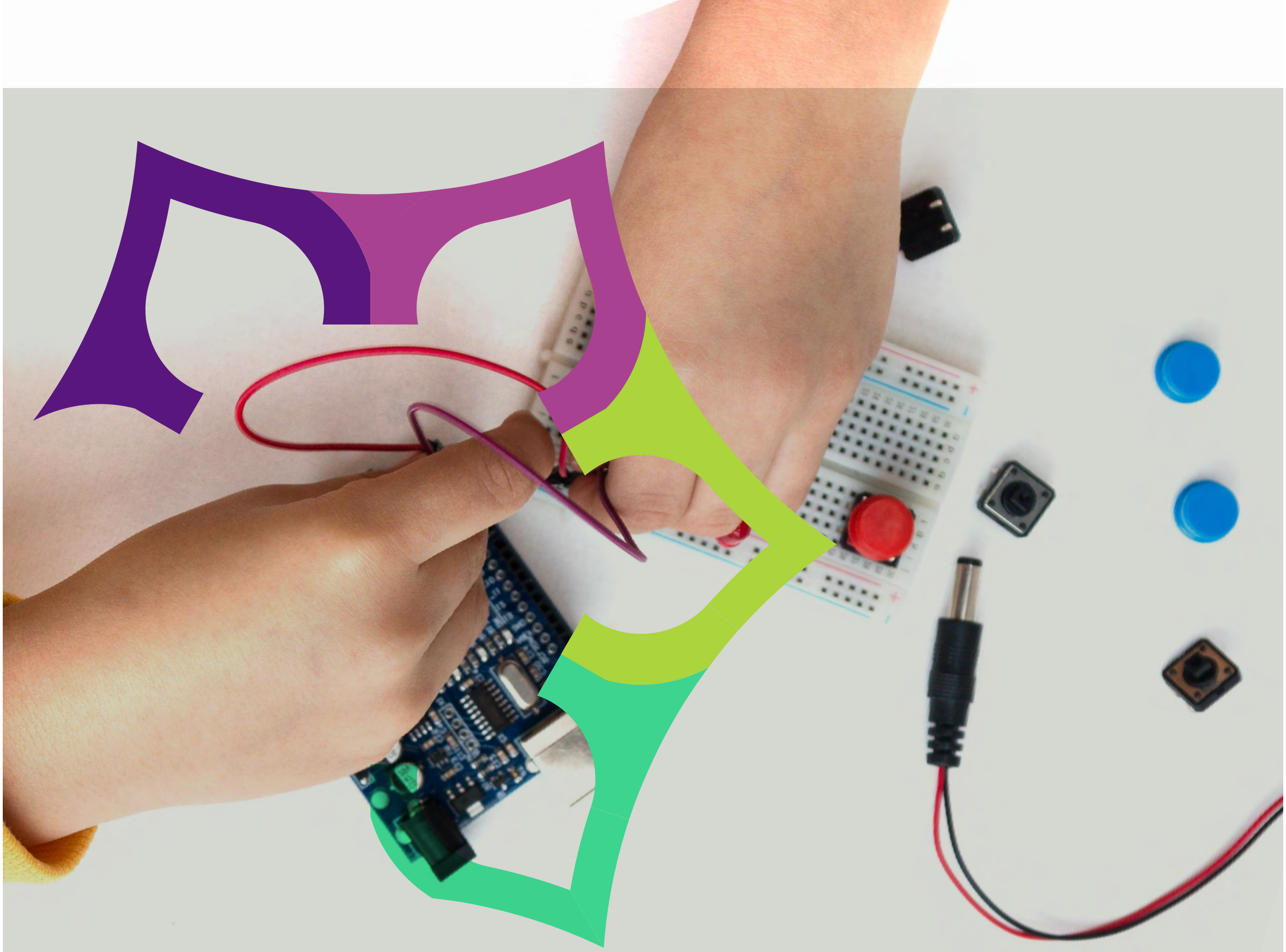

PRODUCT
IOE3

Erasmus+ 2019-1-ES01-KA204-065615 Project

# Enrichment Toolkit, intellectual product (OIE3) from the Smart Art project

Teaching-learning for STEM subjects

**srlsmartart.eu** srlsmartart srlsmartart smartartproject


UNIVERSIDAD DE BURGOS
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Universidad de Valladolid
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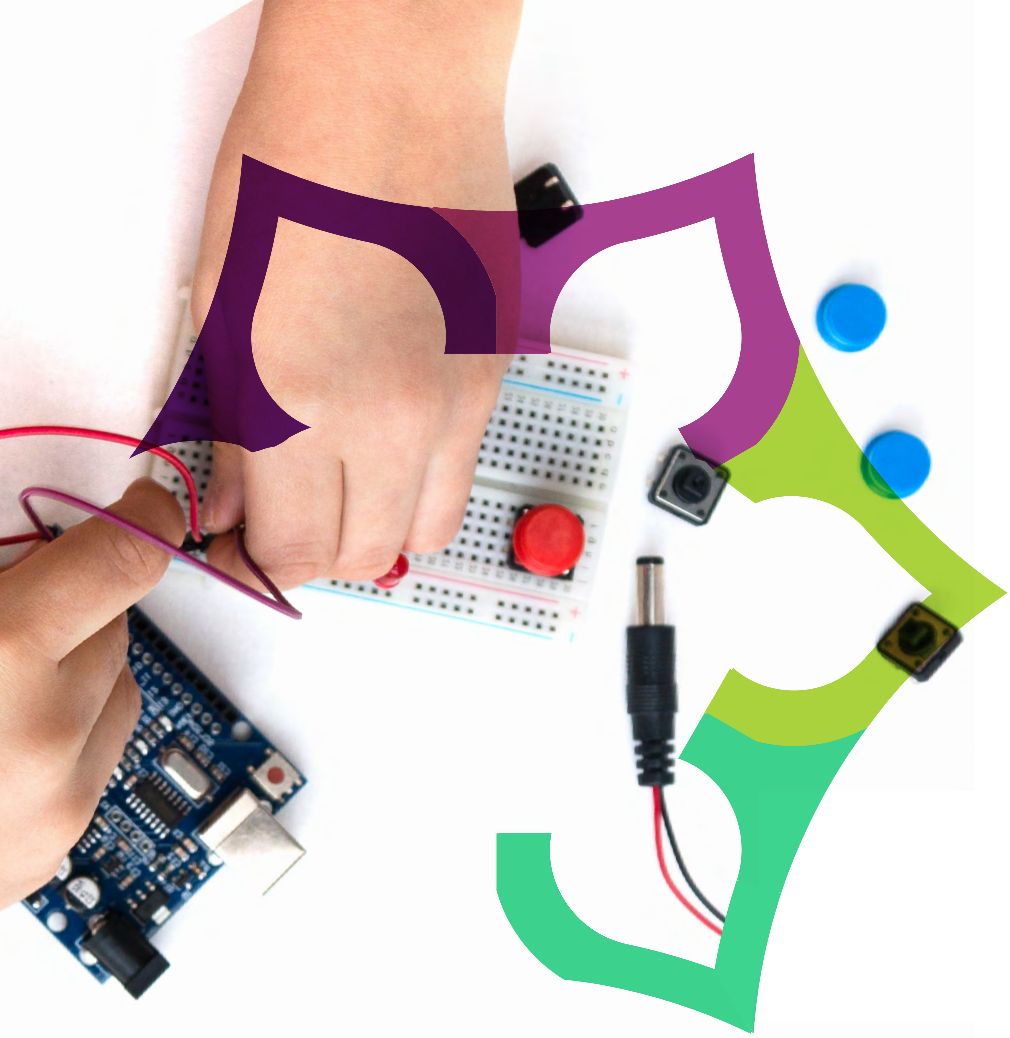
SMART art

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Inclusive language has been used throughout the document. However, in those sentences or sentences where the masculine gender has been used for the sake of clarity, it has been used in the global sense to refer to the different genders.


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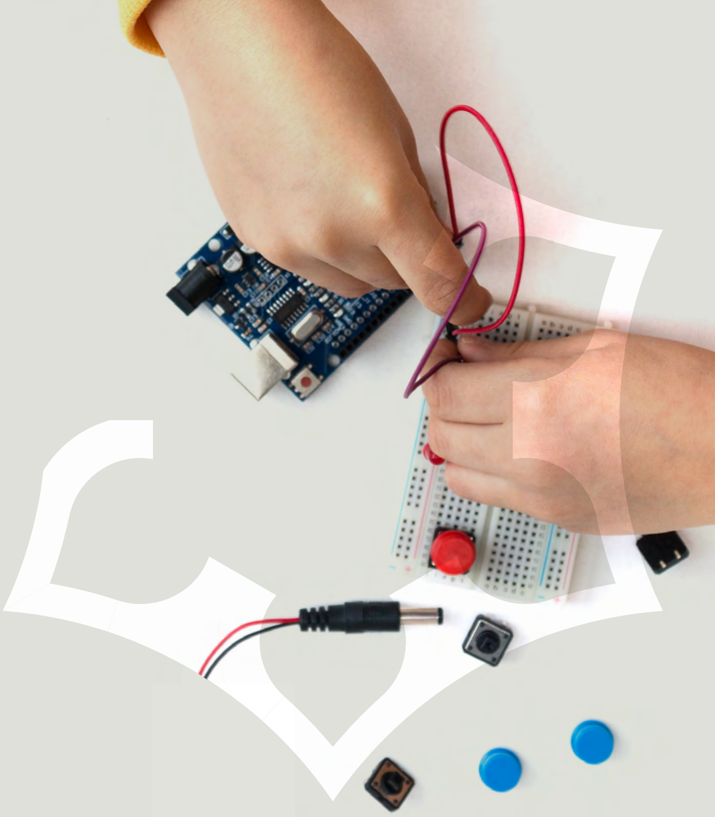


# TOOLKIT OIE3

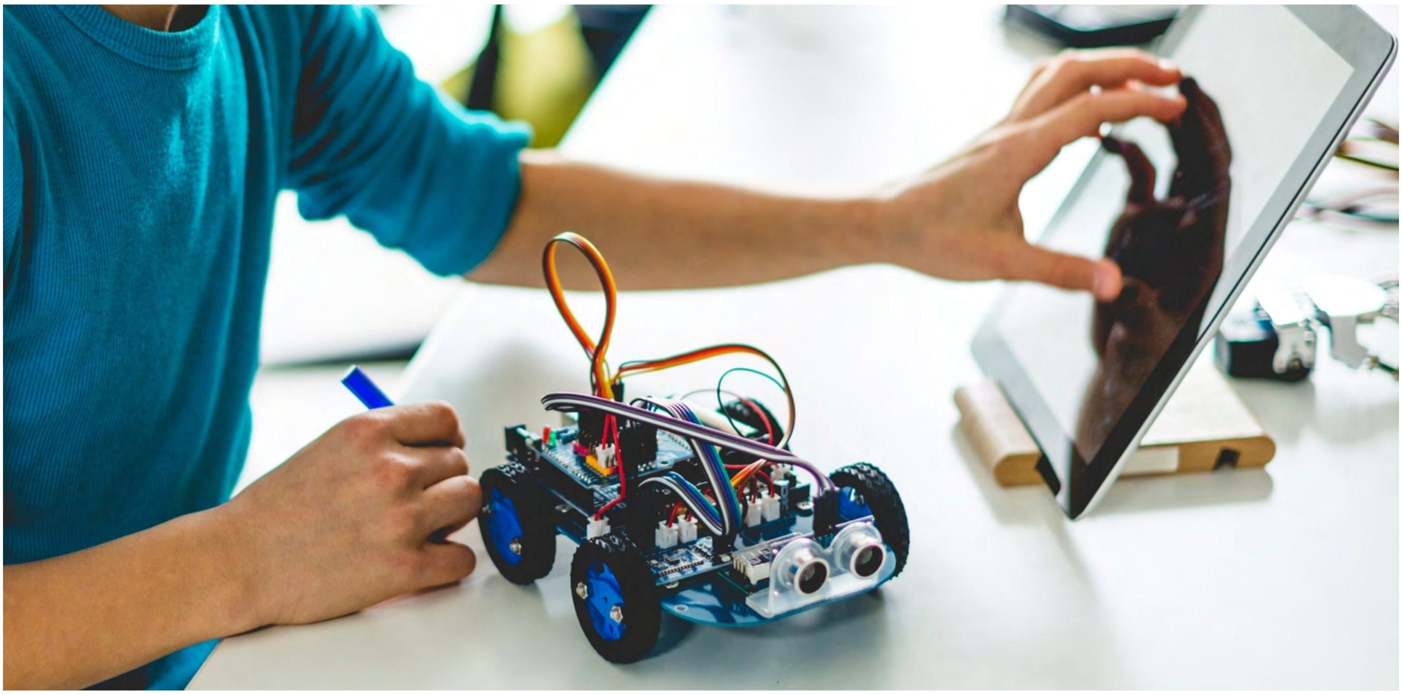
## Index

# Why are we targeting students in compulsory secondary education?

1

Many students drop out of STEM subjects in compulsory secondary education. This situation has been described by numerous authors with the metaphor of a leaky pipe that begins when students finish primary school and interest in STEM subjects decreases as they progress through the educational system. This disengagement from scientific-technological education is also clear in the transition from secondary education to tertiary education and, furthermore, this trickle continues during higher education, with approximately one third of students dropping out of STEM courses. The factors affecting retention of students include students previous levels of performance at school (Sáiz-Manzanares et al., 2020; Ulriksen et al., 2015).

This situation is not new and is a cause for concern at all educational levels, particularly in higher level courses due to the profound impact on national and transnational higher education programs. In order to increase the number of graduates from STEM courses, higher numbers of new students are needed, and for this to happen, students' interest in scien-



tific-technological disciplines must be enhanced from early educational stages onwards (Boiko et al., 2019; Henriksen, 2015). Physics is one of the scientific-technological disciplines with the lowest academic performance in secondary education. Students often feel it is difficult and unappealing compared to other scientific-technological disciplines, yet it is one of the most important subjects in STEM courses (Guido, 2018; Sáiz-Manzanares & Bol, 2015).

The literature shows how certain educational approaches improve students' academic performance and their attitudes towards science. Integrating disciplines with a STEM/STEAM approach, using real teaching-learning contexts, and incorporating ICT can increase students' interest in these disciplines. Incorporating these educational approaches into the classroom requires using active methodologies such as inquiry and problem solving, which also enable students to acquire scientific-technological skills and develop 21st century skills (Diez-Ojeda et al., 2021; López-Iñesta et al., 2021; Queiruga-Dios et al., 2019a, 2019b, 2020, 2021a, 2021b, 2021c; Queiruga-Dios et al., 2021). Among these competences that students acquire and develop is learning to learn, related to self-regulated learning (SRL) (Salmerón-Pérez & Gutiérrez-Braojos, 2012).

# 2 Methodology that has been implemented

SRL is a process in which students establish their own learning goals, monitor their progress, and adapt and regulate their cognition, motivation, and behavior to achieve those goals. In order to regulate their learning, students need to use appropriate learning strategies when solving a problem or performing a task. The most capable students in self-regulation are more aware of the mistakes they make as well as possible ways to carry out the task, self-regulating their behavior and calibrating or modifying their strategies if necessary (Sáiz-Manzanares et al., 2019b; Sáiz-Manzanares & Valdivieso-León, 2020).

Proper metacognitive strategies are needed to learn science, and especially physics, where the plethora of extant alternative concepts mean that learners need to activate suitable comprehension strategies allowing them to detect understanding of scientific content. If students do not detect these alternative ideas, they will not take measures to modify them either (Mateos, 2001; Queiruga-Dios et al., 2021d).

Learning management systems (LMS) or learning platforms can facilitate students' self-regulatory training as such systems allow students to be guided through the content and have teacher-student feedback (Saiz-Manzanares et al., 2017). LMS are effective in achieving student SRL when properly designed and implemented. This design must include the analysis and detection of students' alternative ideas, learning tasks designed with a constructivist approach, and process-oriented feedback so that each student can learn from the mistakes they make (Sáiz-Manzanares et al., 2021, Sáiz-Manzanares et al., 2019a).

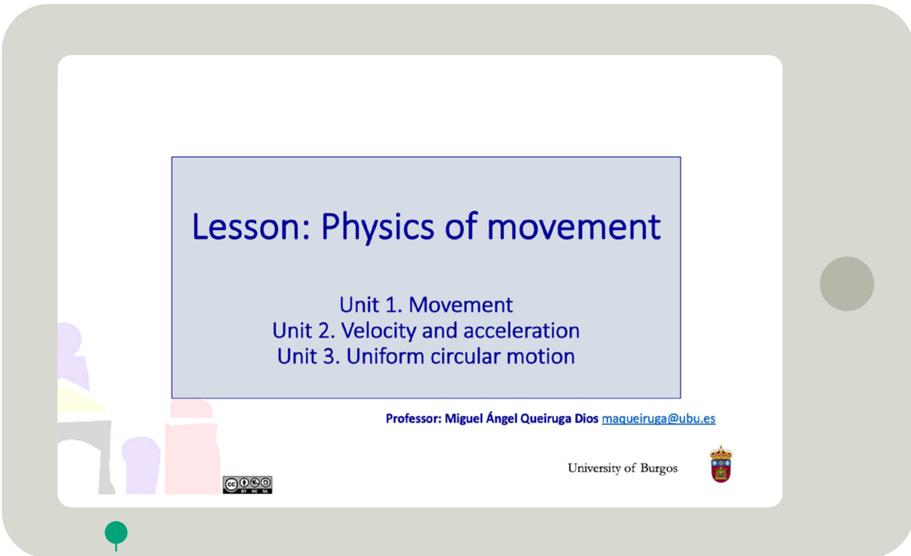
The use of methodological approaches based on SRL is effective in the teaching-learning process in the sciences. They help students develop the capacity for organization and self-regulation of their own learning, overcoming difficulties that arise in doing tasks, and improving their academic performance (Sáiz-Manzanares & Valdivieso-León, 2020; Queiruga-Dios et al., 2021d).

The STEM educational approach and self-regulated training of students make scientific-technological disciplines friendlier and avoid gender biases. They increase student interest in these disciplines and decrease dropout rates, presumably increasing the number of subsequent scientific careers. In this regard, teachers have an essential role, and their influence must be taken into account since it can affect students' decisions about their learning pathways and choice of subjects from a very early age. This can help reduce that constant ongoing leak that worsens towards the highest academic levels. Thus, teachers can guide the teaching-learning processes and support student self-efficacy, which is a strong predictor of achievement and persistence in STEM disciplines (Morrison et al., 2020; Redmond & Gutke, 2020).

# Learning activities

## 3

### 3.1. Physics of movement




## Physics of movement

**General aims**

Understand the concept of movement.
Understand that motion and trajectory are relative.
Understand the concept of trajectory.
Understand the different types of movements and the quantities involved (space, time, velocity, acceleration), as well as the units associated with these quantities.

**Specific aims**

Distinguish between the different types of movements based on their trajectories and their velocity from the analysis of real situations.
Represent velocity and acceleration vectors in different types of movements.

**Competences**

Define the concept of position, movement and trajectory.
Recreate different situations that show the relativity of motion.
Explain the concept of velocity / acceleration and its units of measurement.
Explain the direction of the velocity and acceleration vector in different motion situations.
Explain the effect of the acceleration of gravity on motion.

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# Physics of movement

Evaluation criteria:

Before doing this activity, it is useful to know how much people already know about the topics to be covered. To do this, please fill out the following survey.

| EVALUATION CRITERIA | RATING SCALE | | | | |
|---|---|---|---|---|---|
| **Unit 1. Movement** | | | | | |
| 1. I can explain the concept of changing the position of a body or object. | 1 | 2 | 3 | 4 | 5 |
| 2. I can explain the concept of motion. | 1 | 2 | 3 | 4 | 5 |
| 3. I can explain the reference system concept. | 1 | 2 | 3 | 4 | 5 |
| 4. I can explain the concept of trajectory. | 1 | 2 | 3 | 4 | 5 |
| 5. I can explain what rectilinear motion is. | 1 | 2 | 3 | 4 | 5 |
| 6. I explain what a curvilinear motion is. | 1 | 2 | 3 | 4 | 5 |
| 7. I can explain the relativity of a motion. | 1 | 2 | 3 | 4 | 5 |
| **Unit 2. Velocity and acceleration** | | | | | |
| 1. I can explain the concept of velocity. | 1 | 2 | 3 | 4 | 5 |
| 2. I can explain the units of measurement of velocity in the International System of Units. | 1 | 2 | 3 | 4 | 5 |
| 3. I can explain the concept of vector magnitude. | 1 | 2 | 3 | 4 | 5 |
| 4. I can explain the concept of uniform motion. | 1 | 2 | 3 | 4 | 5 |
| 5. I can explain the concept of acceleration. | 1 | 2 | 3 | 4 | 5 |
| **Unit 3. Uniform circular motion** | | | | | |
| 1. I can explain circular motion. | 1 | 2 | 3 | 4 | 5 |
| 2. I can explain the concept of normal acceleration. | 1 | 2 | 3 | 4 | 5 |
| 3. I can explain the relationship between velocity and acceleration in a uniform circular motion. | 1 | 2 | 3 | 4 | 5 |

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# Physics of movement

Welcome to this learning space, this time to talk about the physics of movement.

And, as it is often said that the movement is shown to be well done. Do you dare to walk with me?



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# Unit 1. Movement

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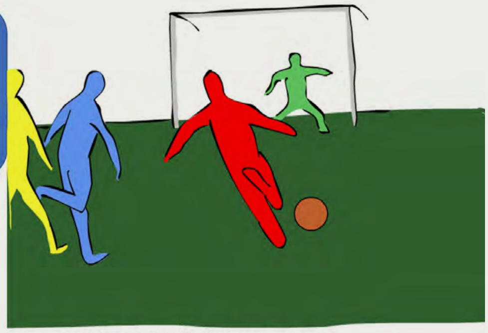
## Unit 1. Movement: definition

The concept of **movement** is very intuitive to us.
In a soccer game, we observe how the ball moves, and after it, the players; and we look at the goalkeeper, who seems not to move, at rest, watching...



*Around us we continually observe moving objects.*



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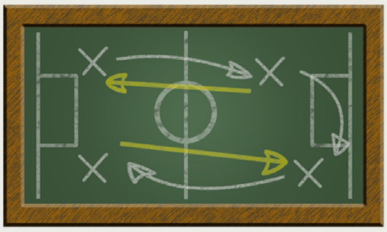
## Unit 1. Movement: position



Therefore, defining movement as the change in position experienced by a body or an object does not cause us any uneasiness.
But ... what do we call position then?

The position of an object is simply, *where an object is*. Mathematically, the position can be expressed by means of coordinates with respect to a point that we take as a reference.

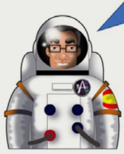
When I say, for example, that the ball is two steps to my left and one step forward, I am expressing the coordinates of its position. For each of the players the position of the ball would be different: each would have to take a different number of steps to reach it. With respect to each observer, the position of an object is different!
Instead of little steps, the International System of Units uses the meter.

## Unit 1. Movement: International System of Units

In short, we say that a body moves when its position changes over time.
Therefore, for the study of a movement, it will be important to define a point that we will take as a reference system, and to have instruments that allow us to measure positions and times.



To study movement, we need to measure positions and times.



As noted, in the International System of Units, the positions and distances between two things are expressed in meters.
Time is expressed in seconds.

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# Unit 1. Movement: trajectory

You will have noticed that not all objects move the same way.
I mean, when I see my classmates walking down the hall, I see that they move in a straight line. But, if I try to throw a ball of paper into a wastebasket, it moves in a curve.

The amusement park can also provide many examples of movements: people on the rides move through all kinds of curves.



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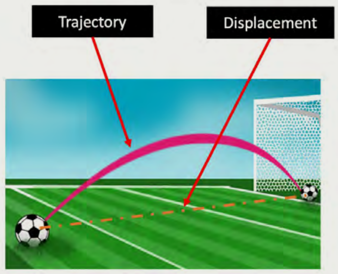
# Unit 1. Movement: trajectory and displacement

Well, the road, the curve that describes a **moving object**, let's call it **trajectory**.

We must not get confused between trajectory (the curve that describes the moving object) and displacement, which is the distance between two positions.




Trajectory and displacement of soccer ball.

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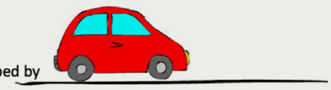
# Unit 1. Movement: classification according to trajectory

If we consider the trajectory described by a moving object in its movement, we can classify movements as...

- **Rectilinear**, if the trajectory described by the moving object is a line.
- **Curvilinear** , if the trajectory described by the moving object is a curve. This includes **circular motion**, which is the movement of an object whose trajectory is a circumference: the drum of a washing machine spinning, the wheel of a moving car, a spinning Ferris wheel... they perform circular movements.



How is the movement of a car moving along a straight line of the road?

How is the movement of the horses on a merry-go-round?



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# Unit 1. Movement: relativity

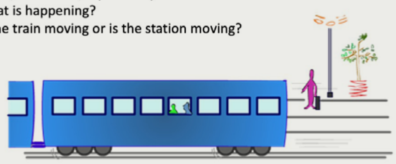
Let's get on the train to reflect on movement! Read, reflect and try to answer the questions...

The train leaves the station, and the passengers have already settled into their seats. Inside the car I see countless objects that are at rest: the seats, the passengers, the windows. All these objects are always in the same position. On the table I have my laptop and my notes. I always see them in the same place, neither forward nor further back, neither to one side nor the other. They are always in the same place. They are at rest (remember that the movement was a change in position).

But now I look out the window... and I see trees passing by! And now... a telephone pole! I put my nose to the window and, looking ahead, I see a house getting closer and closer, and closer, it passes by the train and then further back and further back...

What is happening?

Is the train moving or is the station moving?



Who or what is moving? On the next page I tell you my conclusion.



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# Unit 1. Movement: relativity

Have you come to the same conclusions as me?

If I am sitting on a bench in the station, and I see the train leave, it will seem obvious to me that it is moving: its position is changing, I see it further and further away, as well as its occupants.

In the same way, what I observe when I am on the train is that the house, the tree or the pole are not always at the same distance from me, I do not always see them in the same position. If we remember that definition of movement that seemed so obvious to us a few lines ago (when I see that an object is not always in the same position, with respect to me? It moves), I can affirm that all those objects are in motion. So, taking all this into account, we can say that the movement depends on the observer: **movement is relative!**

After this conclusion, we cannot absolutely affirm that such an object is at rest or is in motion. To be precise, we must say that a body is at rest or in motion with respect to a certain observer, with respect to a certain reference system.

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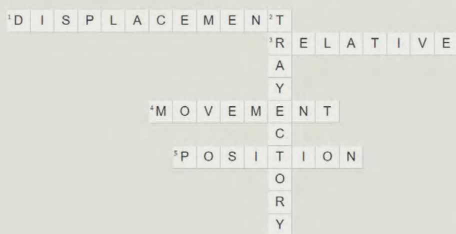
# Knowledge check




## Across

1 Distance between two positions of a moving object

3 Depending on who is watching the movement (and trajectory) is

4 Change in the position of an object

5 Place where an object is located

## Down

2 The curve that a body describes in space

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# Unit 2. Velocity and acceleration

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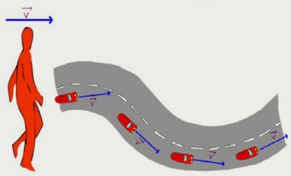
## Unit 2. Velocity and acceleration

So far we have talked about the concept of movement and trajectory. We are now going to talk about a concept that refers to how "fast" or "slow" a moving object moves: **velocity**.

If I start to walk taking one step every second, I can express the velocity of my movement precisely like this: one step per second.
If I increase the pace to two steps per second, now I move faster. Twice as fast?
We are then going to use velocity to give a measure of how fast a movement is. So, I will say that in the previous cases, my velocity was one step per second and then it was two steps per second.
In the International System of Units, length is expressed in meters and time in seconds. Therefore, the velocity of a moving object will be expressed as how many meters it travels in one second (m/s). Other units are also used to express velocity; in vehicle speedometers we can see that the velocity at which it travels is expressed in kilometers per hour or miles per hour.

## Unit 2. Velocity and acceleration: the concept of velocity

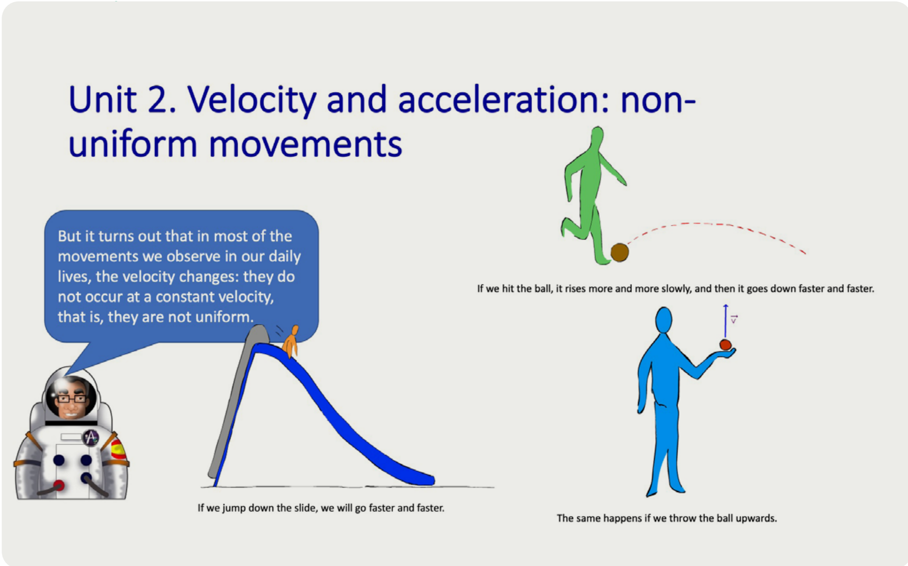
But, to express velocity, is it enough to indicate the "quantity" followed by a few units? For example, say : *"I'm moving at 20 m/s"*, Is that enough information for the listener? They will surely wonder : *yes, but where to?*

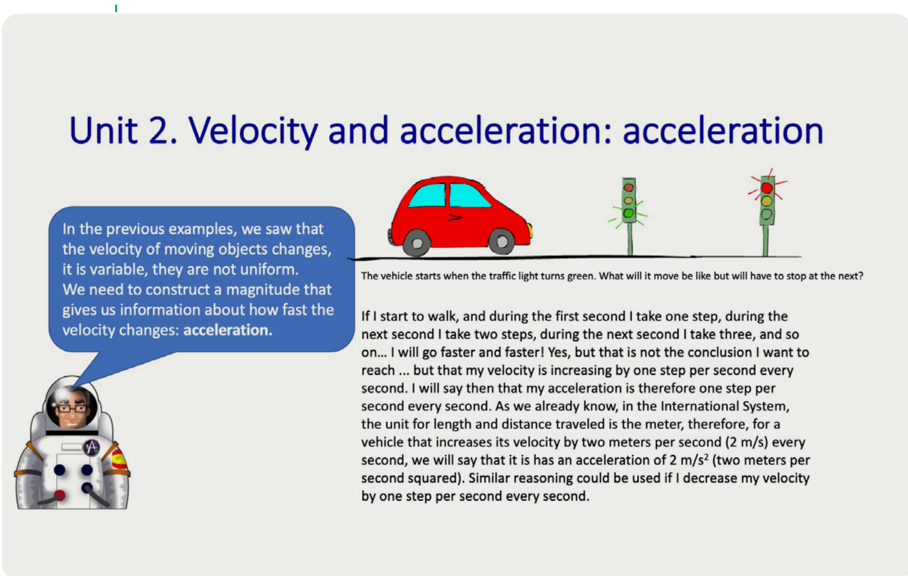


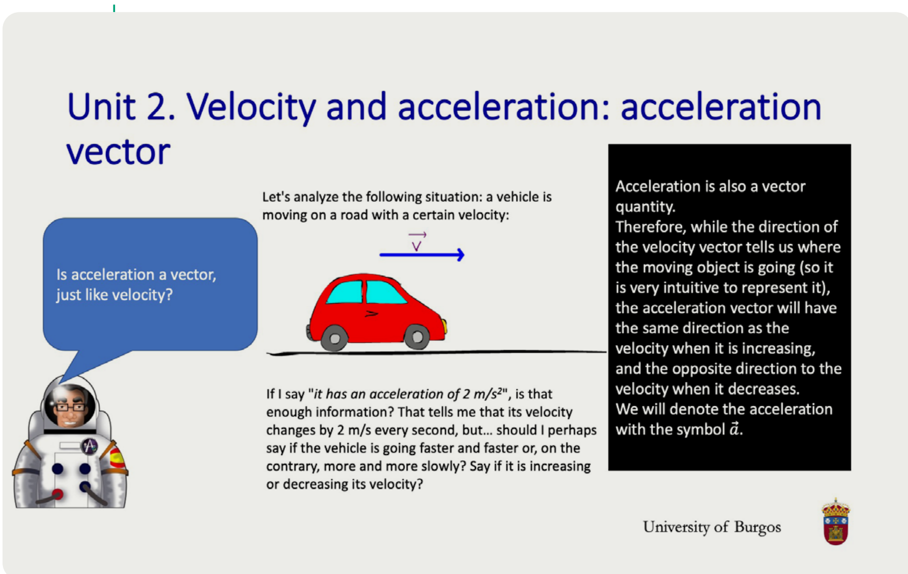
We indicate the direction and the sense of movement of an object with the velocity vector. Do you give us any other information?
The velocity at each moment tells us where the vehicle is moving.

In order for this magnitude to be fully determined, in addition to the quantity, I must indicate in which direction the moving object is moving; it is therefore a vector magnitude.

A movement in which the velocity does not vary, is called **uniform movement.**


Unit 2. Velocity and acceleration: non-uniform movements
But it turns out that in most of the movements we observe in our daily lives, the velocity changes: they do not occur at a constant velocity, that is, they are not uniform.
If we hit the ball, it rises more and more slowly, and then it goes down faster and faster.
If we jump down the slide, we will go faster and faster.
The same happens if we throw the ball upwards.


Unit 2. Velocity and acceleration: acceleration
In the previous examples, we saw that the velocity of moving objects changes, it is variable, they are not uniform. We need to construct a magnitude that gives us information about how fast the velocity changes: **acceleration.**
The vehicle starts when the traffic light turns green. What will it move be like but will have to stop at the next?
If I start to walk, and during the first second I take one step, during the next second I take two steps, during the next second I take three, and so on... I will go faster and faster! Yes, but that is not the conclusion I want to reach ... but that my velocity is increasing by one step per second every second. I will say then that my acceleration is therefore one step per second every second. As we already know, in the International System, the unit for length and distance traveled is the meter, therefore, for a vehicle that increases its velocity by two meters per second (2 m/s) every second, we will say that it is has an acceleration of 2 $m/s^2$ (two meters per second squared). Similar reasoning could be used if I decrease my velocity by one step per second every second.


Unit 2. Velocity and acceleration: acceleration vector
Is acceleration a vector, just like velocity?
Let's analyze the following situation: a vehicle is moving on a road with a certain velocity:
$\vec{v}$
If I say "*it has an acceleration of 2 m/s²*", is that enough information? That tells me that its velocity changes by 2 m/s every second, but... should I perhaps say if the vehicle is going faster and faster or, on the contrary, more and more slowly? Say if it is increasing or decreasing its velocity?
Acceleration is also a vector quantity.
Therefore, while the direction of the velocity vector tells us where the moving object is going (so it is very intuitive to represent it), the acceleration vector will have the same direction as the velocity when it is increasing, and the opposite direction to the velocity when it decreases.
We will denote the acceleration with the symbol $\vec{a}$.
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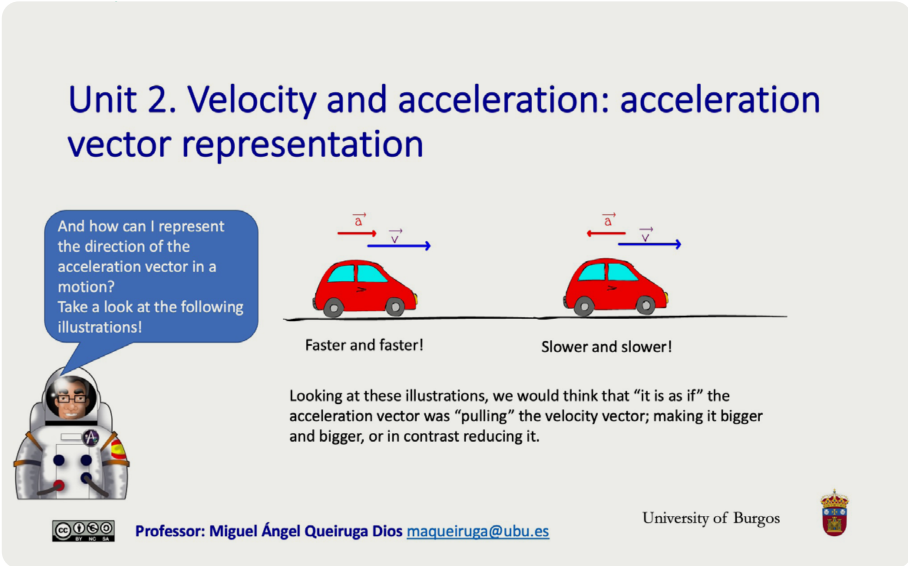
Unit 2. Velocity and acceleration: acceleration vector representation
And how can I represent the direction of the acceleration vector in a motion?
Take a look at the following illustrations!
Faster and faster!
Slower and slower!
Looking at these illustrations, we would think that "it is as if" the acceleration vector was "pulling" the velocity vector; making it bigger and bigger, or in contrast reducing it.
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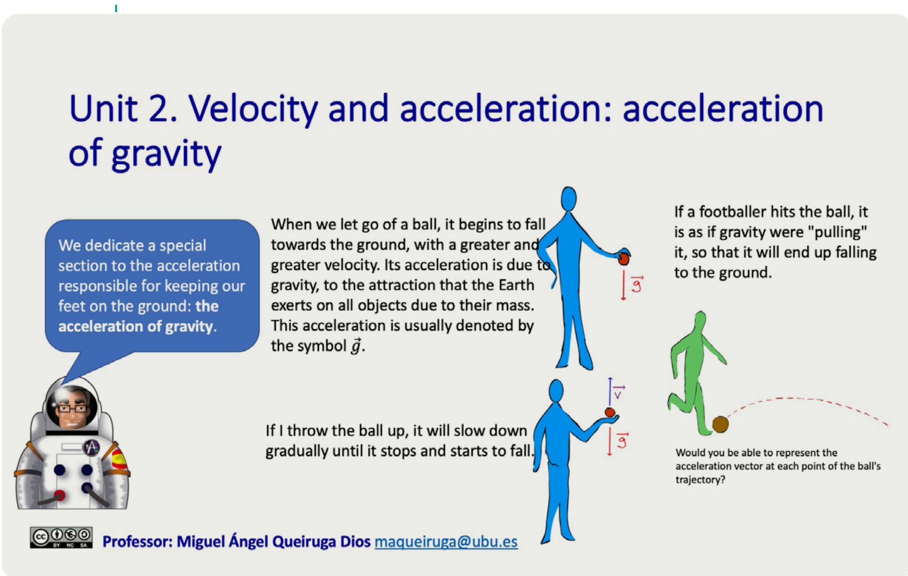
Unit 2. Velocity and acceleration: acceleration of gravity
We dedicate a special section to the acceleration responsible for keeping our feet on the ground: the acceleration of gravity.
When we let go of a ball, it begins to fall towards the ground, with a greater and greater velocity. Its acceleration is due to gravity, to the attraction that the Earth exerts on all objects due to their mass. This acceleration is usually denoted by the symbol $\vec{g}$.
If I throw the ball up, it will slow down gradually until it stops and starts to fall.
If a footballer hits the ball, it is as if gravity were "pulling" it, so that it will end up falling to the ground.
Would you be able to represent the acceleration vector at each point of the ball's trajectory?
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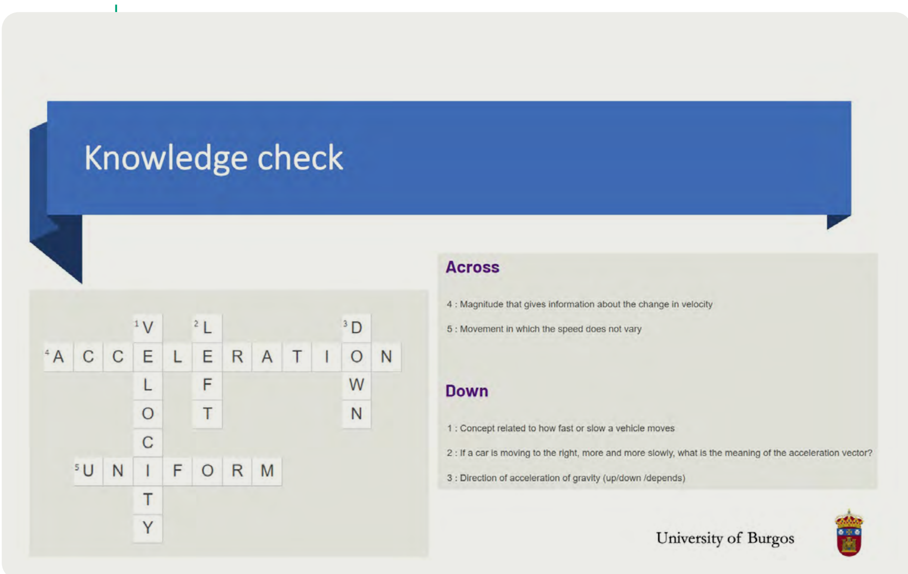
Knowledge check
Across
4 : Magnitude that gives information about the change in velocity
5 : Movement in which the speed does not vary
Down
1 : Concept related to how fast or slow a vehicle moves
2 : If a car is moving to the right, more and more slowly, what is the meaning of the acceleration vector?
3 : Direction of acceleration of gravity (up/down /depends)
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# Unit 3. Uniform circular motion

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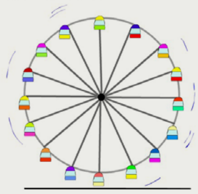
## Unit 3. Uniform circular motion: definition


**Circular motion**, where the trajectory is a circumference, is also everyday for us: a spinning wheel, a Ferris wheel, a merry-go-round. In reality, each curved section that we describe on a road can be considered as a portion of circular motion.

When we go by car and drive round a bend, if we look at the speedometer and see that the velocity does not vary, the movement that we will be analyzing will be a uniform circular movement, during the section that is in the curve.
And if we ride a bicycle with uniform movement, the wheels will be in **uniform circular movement**.



The travelers of a big wheel also perform uniform circular movement, except when starting and when it begins to stop, at those times it is not uniform.

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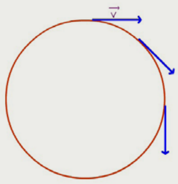
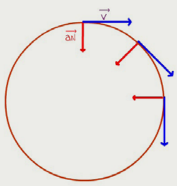
## Unit 3. Uniform circular motion: velocity and acceleration


If we were to represent the velocity vector associated with a moving object that describes a circular motion, this representation would be something like the following:



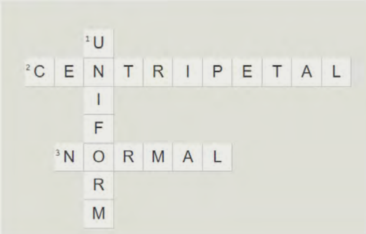

After this representation, it is possible that the first thing we observe is that the velocity vector is actually changing ... it is changing its direction.

Associated with this change in the direction of the velocity, we find an acceleration that causes this change, and it seems that they are "pulling" the velocity vector towards the center of the circumference that the moving object describes.




In a circular motion there is always **normal acceleration** or **centripetal acceleration**. We can denote it as $\vec{a_N}$. This normal acceleration depends on the velocity. The greater the velocity of the moving object that describes a circular motion, the greater the acceleration must be to achieve that change in velocity.

## Knowledge check




**Across**

2 : What other name is normal acceleration usually called?

3 : In a uniform circular motion, there is acceleration. As it is called?

**Down**

1 : If I ride a bicycle with constant speed, what is the circular motion of the wheels like?

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## Generalization activities

- Students will prepare a presentation (using PowerPoint or Prezzi as tools, for example) in which they will capture the main ideas presented by searching for images on the Internet or creating their own images. Each student will present their presentation to the rest of the group. The other students will contribute suggestions and fix possible errors with the help of the teacher.
- They will also produce their own examples in which the following concepts appear: relativity of motion, velocity vector, acceleration vector, rectilinear path, circular path.
- Students who wish can record their presentation on video.

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# Conclusions

4

This enrichment intellectual product (OIE3) from the European SmartArt project offers university teachers of Secondary Education materials that have been created by an interdisciplinary group of participating members in the project who belong to research groups. These materials are also implemented on the project website **https://srlsmartart.eu/** on an open access virtual interactive platform (VLE). The information presented in this document and the VLE and project website will no doubt be of great interest to teachers and students in this knowledge area. Its usefulness will be tested in subsequent studies which will be presented as evaluation reports about its usefulness and will identify improvement opportunities as part of a process of continual improvement.

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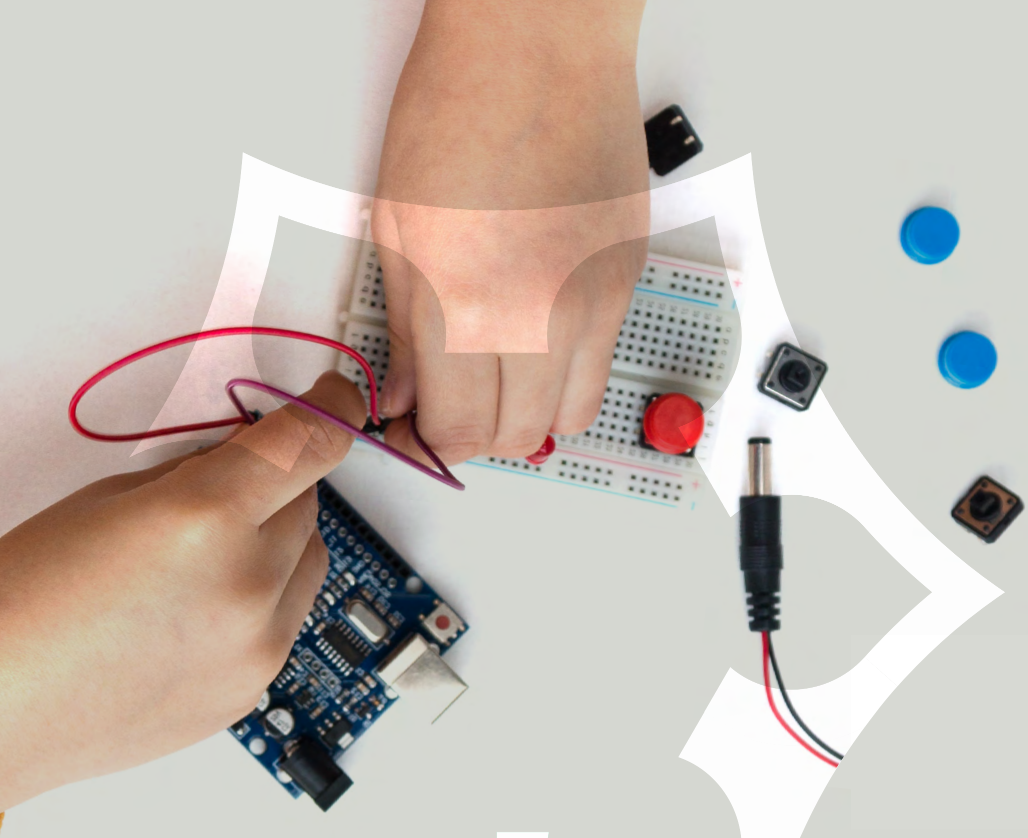
# Image references

The images are of own elaboration.



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