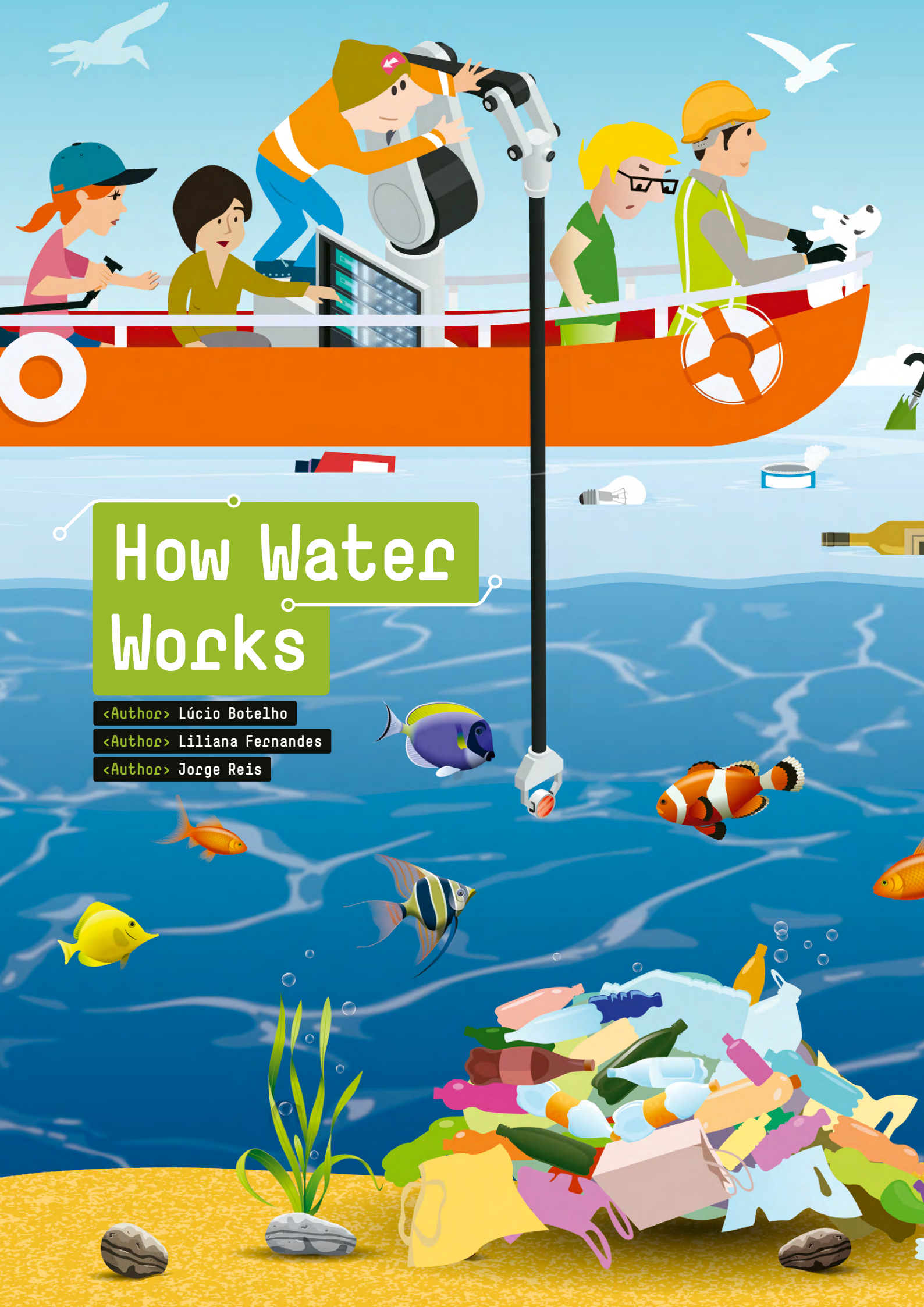

How Water Works

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<Info>

<Keywords> water, image processing, data acquisition, microclimate, robots

<Disciplines> mathematics, biology, social studies, robotics, arts

<Age level of the students> 6–10, 11–15 and 16–18

<Hardware> <easy level> Calliope mini[1], LEGO We Do 2.0[2], small learning bots[3], WeeeMake[4]
<medium level> LEGO EV3[2] with LEGO ultrasonic and colour sensors, or Anprino[5] with Arduino[6] and appropriate ultrasonic[7] and colour sensors[8]
<advanced level> computer with Internet access

<Language> Snap![9], Scratch[10], WeeeCode[4], Open Roberta[11], LEGO Blocks[2]

<Programming level> easy, medium, advanced

<Summary>

This unit was designed to be transdisciplinary in nature, i.e. facilitate collaborative work between students of different levels, from primary to secondary school age. Alternatively, each part can be taught at its own level individually. Starting with a computational thinking approach, to coding in Scratch[10], through to programming robots and an ecological house, in the teaching unit 'How Water Works' students will discover everything about the topic of water.

<Conceptual introduction>

This project is all about water, its role in our life and our role in preserving it. Divided into three levels (easy for primary school students, medium for middle school students, and advanced for secondary school students), this project can be adjusted for collaborative work at different school levels and in cross-curricular activities.

<What the students/teachers do>

<Easy level: Where does water come from?>

The students will be challenged to investigate where water comes from. The teacher will ask questions to stimulate the students' interest and then … the adventure will start! The students will research, learn and then share their findings with their classmates. At the same time, the students will start to develop their computational thinking skills with easy challenges that teach them how to program simple bots.

After finishing their research, the students will start to work in small groups and build some beginner projects using the demo modes of the WeDo 2.0 app[12] with special emphasis on water-related tasks.

Then the students must build an ecological solution, using any bricks or set they want, in which they present an innovative approach to save water.

In the example below, the students built an ecological house[13] and combined it with some extra bricks and the WeDo 2.0 set. Then they added a rainwater collector connected to a filter (coded with the LEGO app) that directed the water into the farm so the animals could drink fresh water (📷1).

📷 1: An ecological house

At the same time, the students, still working in small groups, will start to plan and design new mats related to water for small learning bots that could be programmed without a computer. By presenting their mats to other students, they will motivate them to code and learn about water at the same time. The students can use various low-cost learning robots to do the task.[3]

Full instructions on how to print the mats are available online.[14]

📷 2: Students designing mats

You will also find a link to a step-by-step unit plan in the additional online material.[14]

<Medium level: Building a water dam cleaning robot >

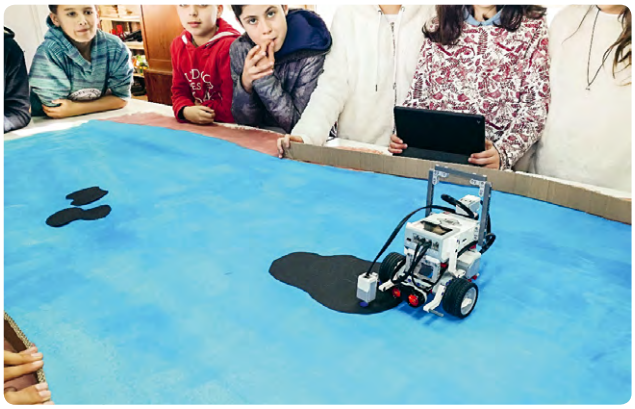
The dam cleaning project is about a robot that travels through the water reservoir created by a dam and detects solid waste.

This project has two versions, using two different robots. The LEGO version (3) uses the EV3 LEGO Education kit; the Anprino robot[5], which is printed using a 3D printer and then assembled, is the work base in the Arduino version (4). The Arduino microcontroller[6] and its range of accessories are attached to the Anprino.

3: The LEGO version

4: The Anprino version

Start by building the water reservoir model using paper or cardboard. It should measure about 2 m × 1 m and be painted blue to simulate water. Build the shores using strong cardboard to limit the robots' room to move, and simulate the waste with pieces of black cardboard.



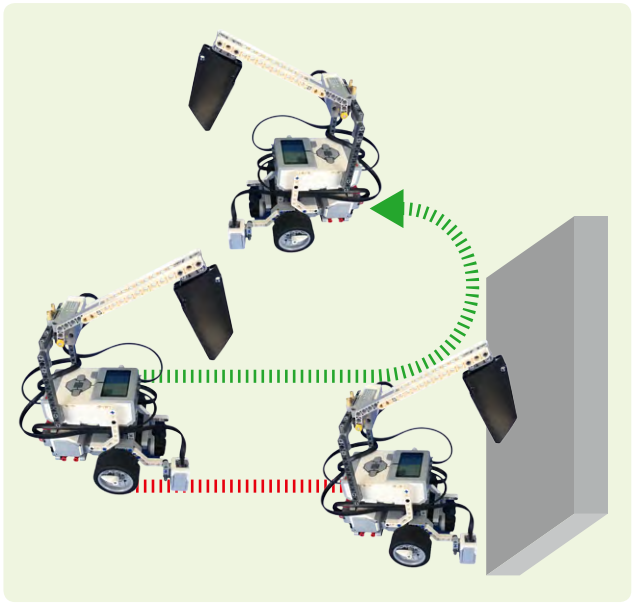
5: Model of the dam reservoir

Ultrasonic sensor

An ultrasonic sensor [7] generates sound waves to detect and measure the distance to the objects. It can also send sound waves to function as a sonar or receive a sound wave that starts a program mode.

Using the ultrasonic sensor, the robot can detect obstacles and react in different ways, depending on the code. The robot could be programmed to stop or change direction, for example. In the dam model, the obstacles are the cardboard shorelines.

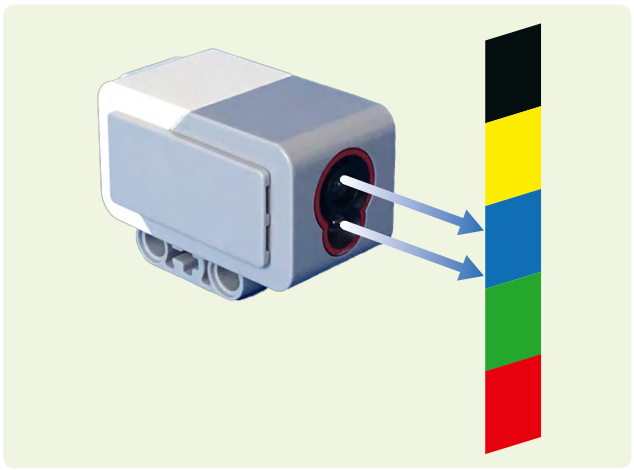
6: A LEGO ultrasonic sensor



7: Robot stops/Robot changes direction

Colour sensor

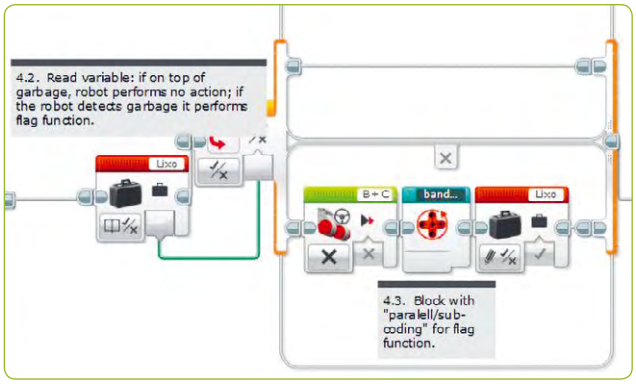
The colour sensor[8] can detect different colours and the absence of light. It works as a light sensor as well by detecting varying intensities of light. Students can build different colour lines for the robot to follow.



8: An example of a colour reading sensor: It distinguishes colours by reading their RGB code.

Building code, using LEGO programming blocks

The students must build different models to simulate distinct kinds of waste, such as domestic, industrial, tourism-related, organic, etc. The main goal is for the students to become aware of river and dam pollution. The students must simulate a waste detector assembled in a boat and then plan and build a waste collector boat at a later date.



9: An excerpt from the LEGO programming; the complete diagram is available online[14]

The robot must play a particular sound for every type of waste that it detects. To achieve this, we use the colour sensor and specific colour 'stains' that simulate each type of waste.

The students can consult the publications of environment/government organisations and build the different stains according to pollution statistics.

The students will go on field trips to rivers and dams to examine the water quality and any pollution. They must then simulate these observations in the models that they build. With the help of the robot, they should scan and note the results in a table (10).

When the students have collected enough results, they must present their research to the class. The goal is for the students to develop their critical thinking, investigation and coding skills. When the students look at what is happening in our waterways, they will see the consequences of centuries of blindness to environmental issues. To be able to understand this, they must have acquired the requisite environmental skills to intervene in their community. For example, this could be by alerting people to the need to prevent behaviour that damages the environment and water in particular. Additionally, they must also be able to plan and present solutions when they detect problems. The overall goal is to increase their civic participation and sense of environmental responsibility in their community.

Please note: our students have already built and tested the LEGO version and are still in the process of improving the Arduino version. The complete code used to program the Arduino is available online.[14]

<Advanced level: Programming educational environment-related games>

The main goal is for the students to become aware of water pollution. The students will use Scratch[10] to program games that motivate others to help to preserve and protect water and thus encourage people not to throw waste into bodies of water.

Our first game simulates a little fish in the ocean. The fish has to feed while, at the same time, avoiding other marine creatures (sharks and crabs) and falling waste (glasses, cans, etc.). The more it eats, the bigger it gets, and the more points the player earns in the process.

The fish must not collide with waste and other fish or it gets hurt and receives a bandage. When it has three bandages, the game is over. This game is funny and not only sensitises children but also adults to the increasing amount of waste in our waterways (oceans, rivers, etc.).

The second game is based on a well-known video game, where a frog has to cross a street. But in our case, the character has to cross a river (using the logs as the water flows quickly) and avoid rubbish as well as other animals (bats and snakes). It can also eat flies to gain extra points.

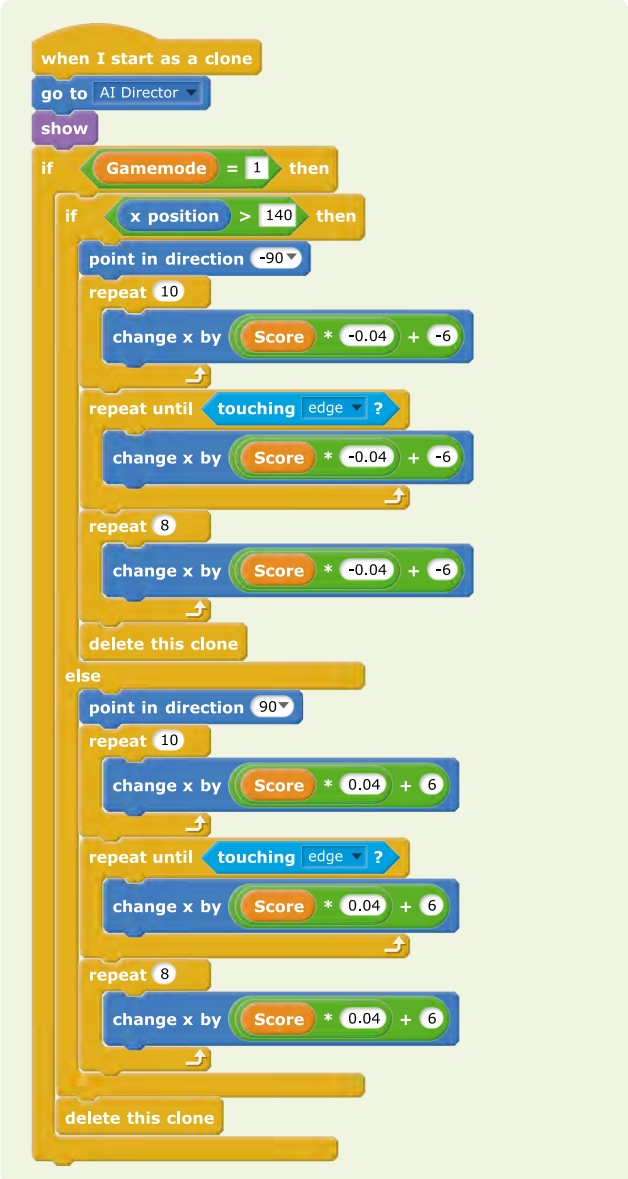
10: Table for waste scan, data related to two different excursions and waste collected in each one by the cleaning teams from the school's environment club

Date	Type of waste					Cleaned Area
	Domestic	Industrial	Undifferentiated	Organic	Others	
Excursion April 2018	3.450 kg			32 kg	8 kg	100 m²
Excursion May 2018	0.730 kg			6 kg		100 m²

In this game, there are four different scenarios and one is selected randomly at the beginning of each round. The frog (sprite) has three lives, after which the game ends.

The following section contains details about the program.

📷11 shows the part of the program that controls the movement of some of the enemies in the various game modes. In the displayed example, the enemy disappears when it touches any of the edges. As long as it is not touching the edges, it repeats the same movement, which also increases in speed with a 0.04 factor adjustment as the player's score increases. This is a very clever way of making the game a little more challenging as the score increases with the increasing level of difficulty.

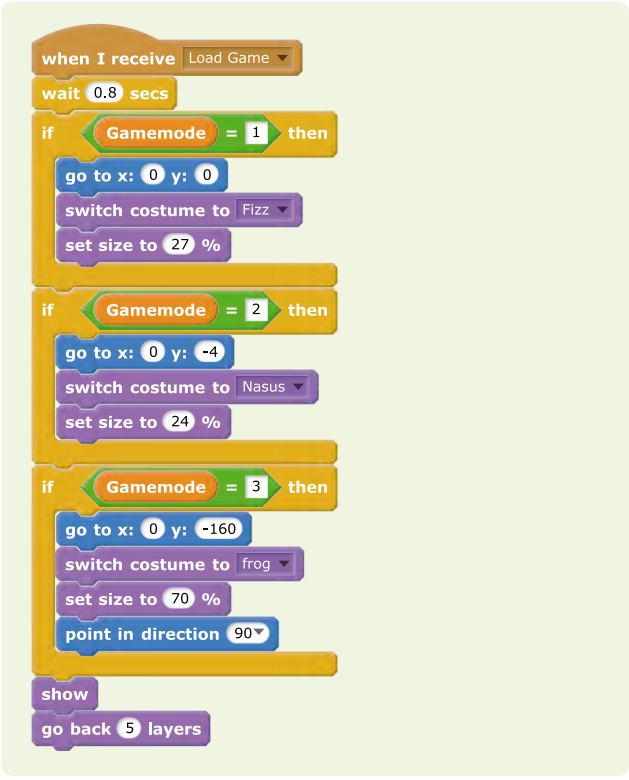


📷 11: Scratch program enemy control

Game start: choose one of three game modes (📷12). At the moment, two games are ready and the students are developing a third one called Game mode 2.

For example, Game mode 2 could be in a pond where ducks have to catch some food.

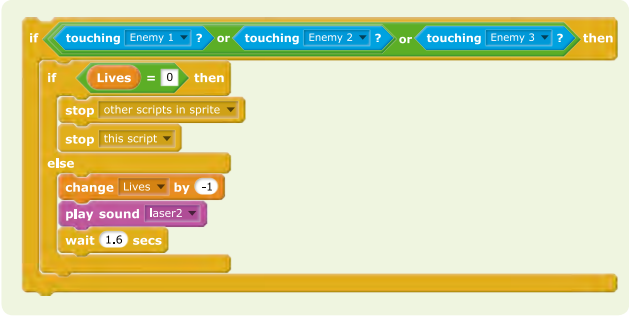
Ducks regularly eat small fish and fish eggs, snails, worms, molluscs, and small crustaceans such as crayfish, grass, leaves, weeds, algae, aquatic plants, roots, small frogs, salamanders and other amphibians. Additionally, the ducks must try to avoid other ducks or waste in the pond (or in advanced levels, random poachers).



📷 12: Scratch program game start

If the fish touches any of the enemies (1, 2, or 3), it loses one life and a sound is heard.

If the player loses all of his/her lives, the game is over, i.e. all the scripts are stopped (📷13).



📷 13: Scratch program enemy 1-3

The game is very well programmed and constructed because the same code is used for the two versions of the game. The same sprite changes its costume from 'Shark' to 'Bat'.

The students will all learn to improve this program by providing new ideas or helping with innovative coding solutions so that the code can be even better and more fluid.

This is possible because the games have similar goals:
↳ avoid enemies
↳ catch food/flies
↳ losing 3 lives means the game is over
↳ earn points (the fish by eating fish food, the frog by eating flies and reaching a new scenario)

They will use clones of the sprite enemy so that they can make the same sprite appear from different directions and have different behaviours (directions) in the game.

The full program is available for download.[14]

<Conclusion>

In this unit, the students will work collaboratively with their peers and their community, and learn and share their knowledge about water: water cycle, water shortage, pollution, etc. They will also develop resources to monitor, save and protect water. At the same time, the students will develop investigative tools and coding skills, as well as skills in the field of robotics. When the oldest students mentor and support the younger ones, they all will motivate and challenge each other to advance their work. This contributes hugely to the success of the projects.

At the end of this school year, we noticed that the students had not only improved their programming skills but were also more conscious of water problems and the dangers for animals and plants, which depend on clean water for the safety of their habitats.

It is not easy to code several games in one. The games must have some similarities so that the code from one can be adapted to serve all modes. However, it is a clever way to save on coding resources.

We chose to work together, although in different schools that are far away from each other, because it allowed us to share ideas and improve the collaborative work between students of varying (social and economic) backgrounds and ages. It was not easy to meet face-to-face or to get the students together as much as we intended, but it turned out to be a good option as it allowed the students to share their ideas and methodologies and to interact with unknown peers, which improved their communication skills. It also offered them the possibility to participate in different competitions and to discuss their results and come up with improvement tips with other students. An alternative to personal meetings could be to communicate online via video conferences. Finally, the students were able to share their work with the community and play a part in changing local attitudes towards water protection.

From this unit, you can challenge your students to develop other ideas and concepts on the topic of saving water, and contribute to improving environmental behaviour in your community and thus reducing the students' and hopefully the community's carbon footprint in the process.

<Cooperation activity>

'Science on Stage is about sharing resources among teachers!'

As a result of this project, a community of teachers was strengthened and resources as well as ideas were shared. This has contributed to better student learning throughout Europe. Sharing and collaborating is the best way for us all to improve and further develop these projects.

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[2] https://education.lego.com
[3] Possible bots: Bee Bots from tts, DOC from Clementoni, Jack from Imaginarium
[4] www.weeemake.com/
[5] Anprino is a robot developed by the Portuguese National Association of Teachers of Information Technology (ANPRI); information and 3D printing files www.anpri.pt/anprino/index.php/anprino-luis (29/11/2018)
[6] www.arduino.cc/
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[8] We used the BE15000624 light sensor.
[9] https://snap.berkeley.edu/
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[13] LEGO SET 31068
[14] All additional materials are available at www.science-on-stage.de/coding-materials.

<Imprint>

<Taken form>
Coding in STEM Education
www.science-on-stage.eu/coding

<Published by>
Science on Stage Deutschland e.V.
Am Borsigturm 15
13507 Berlin, Germany

<Revision and Translation>
Translation-Probst AG

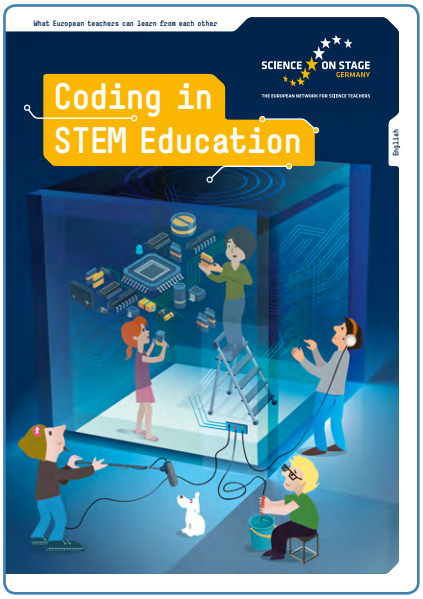
<Design>
WEBERSUPIRAN.berlin

<Illustration>
Rupert Tacke, Tricom Kommunikation und Verlag GmbH

<Please order from>
www.science-on-stage.de
info@science-on-stage.de

<ISBN PDF>
978-3-942524-58-2

First edition published in 2019



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