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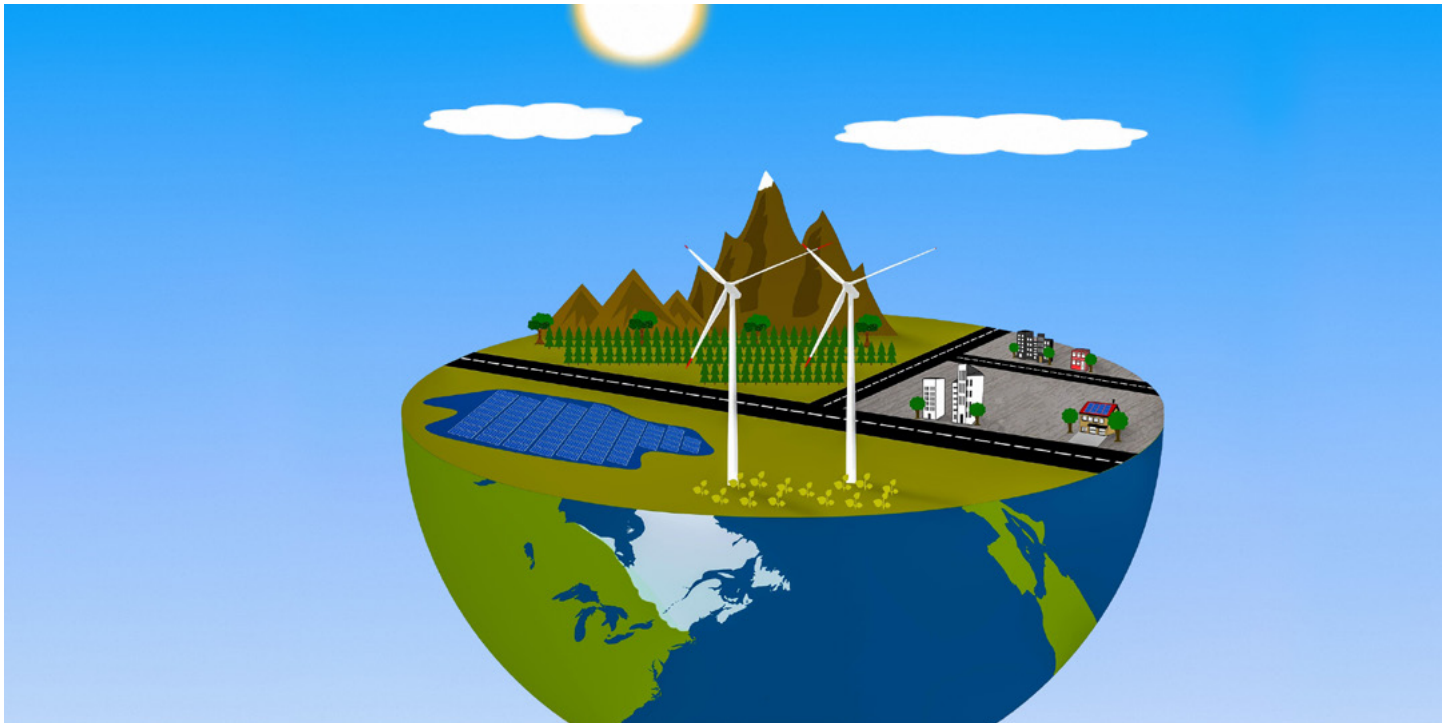


Image: Mollyroselee/pixabay

Explore energy production with the escape game 'Village of the Future'

Soraya Cornelius, Anke Neuhaus

Strengthen knowledge in the subjects of energy supply, grid load, and data evaluation, while using 21st century skills in a fun way.

This activity was presented at the Science on Stage Festival 2024.

Learning in a fun and informal atmosphere is effective and sustainable. Such a learning setting can be created by using educational escape games, enabling students to learn in a practice-oriented way in STEM lessons. This article introduces the 'Village of the Future' escape game for physics or technology lessons. The Village of the Future is an educational escape game about renewable energy for students aged 16 to 19.

Structure of the game

The escape game consists of two parts (figure 1), with the first part focusing on carrying out experiments with solar cells and evaluating these experiments. In the second part, the students work intensively on evaluating diagrams and reading and interpreting information from texts.

Figure 1 shows one possible way to solve the puzzles. To solve the second puzzle, the first puzzle must be solved. The two parts are presented in more detail below.

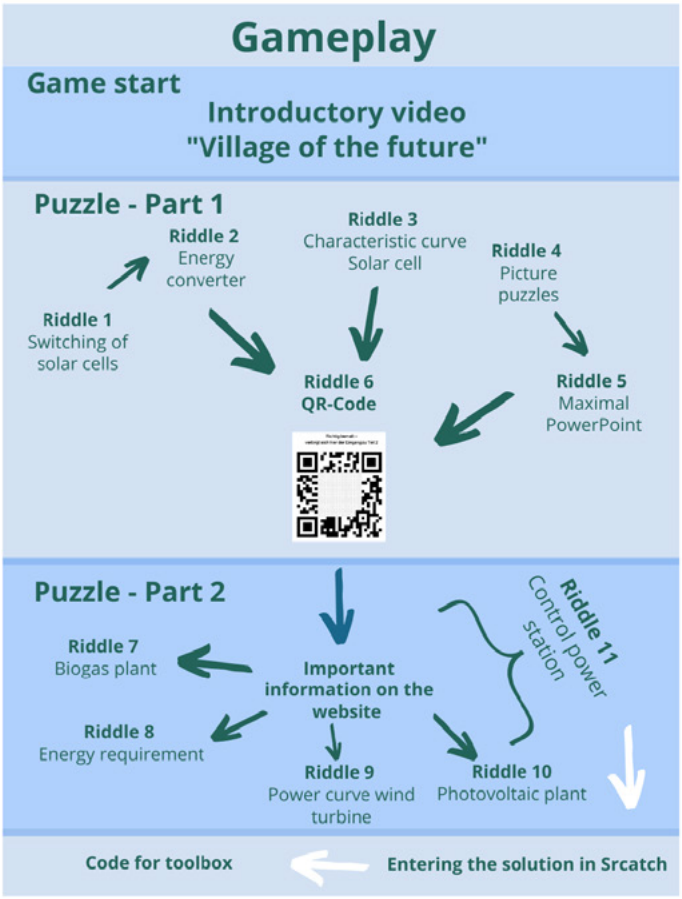


Figure 1: A possible way to complete the escape game
Image courtesy of the author

The game is designed to take 60 minutes, but the recommendation is to plan for a duration of 90 minutes to introduce the escape game to the students, complete the process, and discuss the outcome.

The story

The company Village of the Future helps small villages to become self-sufficient with renewable energy. Many preparations have been made in recent weeks to put the energy network of a small village into operation today. For fear of climate-change deniers disrupting the activation of the renewable-energy grid, the key is kept securely in a toolbox locked with several combination locks. But now the activation of the energy network is endangered because the employee named Ingo, who knows the codes to get the key, is ill in bed and cannot be reached by phone. Luckily, Ingo has prepared puzzles to help find out the codes of the combination locks. The company needs the students' help to solve these puzzles quickly, so that the energy network can go live today.

Preparations before the lesson

Before the lesson starts, all the required materials must be printed out and prepared. The posters should be printed at A3 size, and all other materials should be printed at A4 size and cut out along the indicated lines. It is important that the elements are printed at the correct size or they will not be correctly aligned.

Figure 2: A toolbox prepared for five groups of students.
Image courtesy of the author

Furthermore, a toolbox should be prepared that is locked with the same number of locks with three-number combinations (different colours) as there are groups (figure 2). The codes in the table are set for the different colours of the locks. The toolbox contains a reward (sweets or other treats) and a key (e.g., printed with the 3D printer).

Lock colour	Code
black	975
yellow	965
blue	863
red	973
green	865

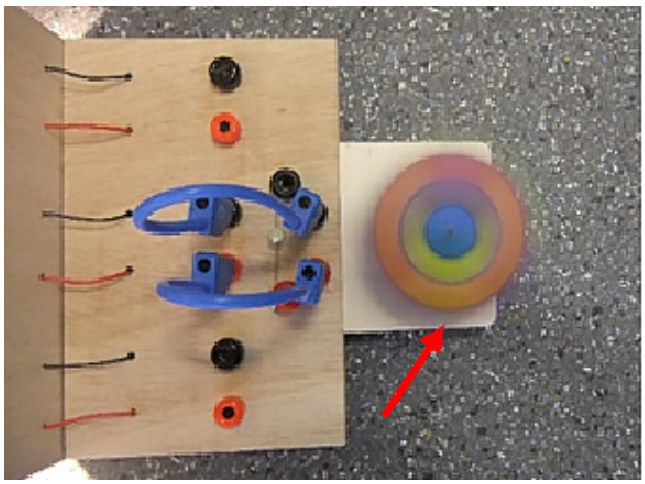
All materials and descriptions required to prepare for the activity, as well as the teacher's manual, in which the teacher receives further tips and information, can be downloaded via the following link.

First puzzle

The aim of the first part of the puzzle is to solve five riddles to find the numbers that are coloured in to complete the QR code in the sixth riddle.

A detailed description of the riddles can be found in the teacher's manual.

Riddle 1: students have to connect the solar cells in series and then in parallel to get light-emitting diodes (LEDs) to light up and a motor to turn. This is required to start riddle 2.



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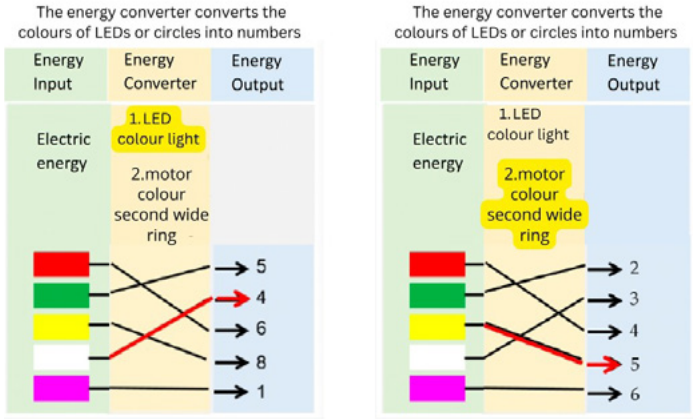
Riddle 2: students find out into which forms of energy the electrical energy is converted in the LED and the motor.



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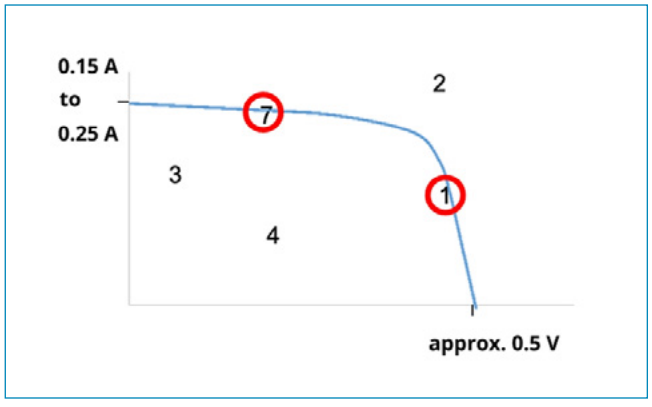
Riddle 3: students have to measure the parameters of a solar cell and find out which of the characteristic curves drawn is the right one.



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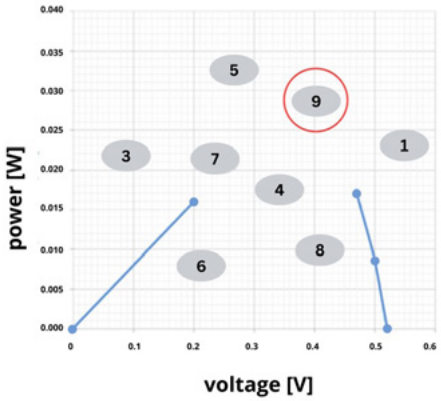
Riddle 4: students must solve a picture riddle to discover what they need (a 5 Ω resistor) for riddle 5.

Word 1: RED + FIST + CANOE → RESISTANCE
Word 2: TAXI + DRUM → MAXIMUM
Word 3: SHOWER → POWER
Word 4: WINE → POINT:
Word 5: FIRE → FIVE
Word 6: OX → OHM

Image courtesy of the author

Riddle 5: students have to find the 5 Ω resistor on the board by using a multimeter, and then connect the large solar cell and measure the voltage and the current to calculate the maximum power point. The result number is nine.



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Riddle 6: students complete the QR code by colouring in the squares numbered two, four, five, seven, and nine, according to the results they have obtained from riddles 2, 3, and 5.
You can decide whether you want to hand out the QR codes in analogue form or make the qrclick.html file QR code available to the pupils. With the analogue QR code, the students fill in the numbers they receive with a black pen and then scan it with a digital device to access the website for puzzle part 2. With the digital QR code, the numbers are filled in by clicking on them, and then the code can be scanned with another digital device.

Image courtesy of the author

Materials

- Prepared toolbox
- Laptop or computer to open an HTML file (internet connection needed)
- Per group:
- Digital device (ideally a tablet) with internet connection and the possibility to scan a QR code
- Story video or background story
- Poster 1 (A3 size) with tasks and riddles for part 1
- Puzzle 1 print materials
- Envelope with:
  - Puzzle 1 transparency with characteristic curve
  - Set of 3 energy output cards (see print materials)
  - The incomplete QR code to fill out (see print materials). Alternatively, the QR code can also be opened digitally and the numbers filled in by clicking on it (see qrclick.html file in the material collection)
- Test unit "solar cells" (see riddle 1 image above) including:
  - Solar cell, small (0.5 V)
  - Solar cell, big (0.5 V)
  - Solar module, which consists of 3 small solar cells connected in series (1.5 V)
  - LED
  - Motor with coloured disc (see print materials)
  - Solar cell hint (see print materials)
- LED spotlight
- Multimeter
- 4 cables
- Resistance board with resistors with the values 2.2 kΩ, 1 kΩ, 100 Ω, 50 Ω, 5 Ω, 1.6 Ω
- Permanent marker

Procedure

1. Divide the students into groups of three or four.
2. Distribute to each group the digital device and all materials needed for the first puzzle.
3. Watch the story video together with the students or read them the background story and afterwards ask if there are any questions.
4. If necessary, explain that the aim of the first part of the puzzle is to find the numbers that are coloured in the QR code.
5. The riddles should be solved in sequence since some riddles depend on the answer from the previous riddle.
6. If necessary, the activity can be paused at the end of puzzle 1 to continue in the next lesson.

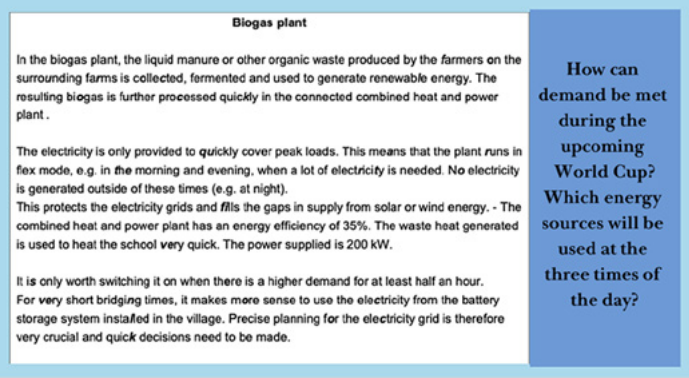
Results

Students should obtain the numbers four and five (riddle 2), seven and one (riddle 3), and nine (riddle 5). These squares should be coloured in on the QR code, so that it can be scanned. By scanning the QR code, students can access the puzzle 2 website, where they can find important information for the second puzzle.

Second puzzle

The aim of the second puzzle is to find the numbers required to open the combination lock by solving five more riddles.

Riddle 7: students need to find the code from information text on a biogas plant to obtain the three clock times they need to solve riddles 9–11. The text also contains important information on the plant parameters, which is needed for riddle 11.



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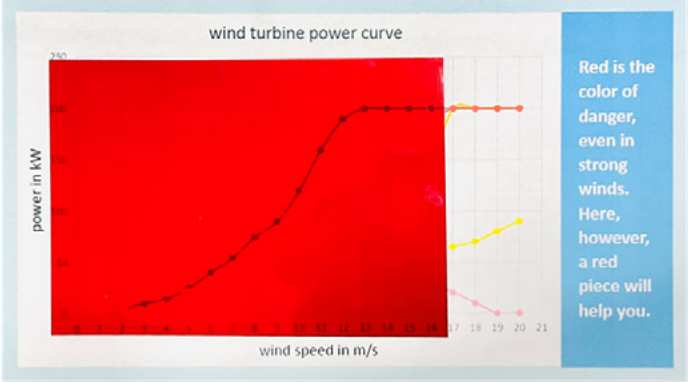
Riddle 8: students assign the cards to the rows in the table on poster 2 by analyzing a text on energy use and evaluating the diagram on electricity demand.

Time of day	Game status	Power demand	
3:00 (p.m.)	Before the game	Less than usual: In preparation of the game, other activities like doing the laundry, washing dishes, hoover the flat, starting the dish washer, ... come to an end.	80 kW
4:00 (p.m.)	First half	The demand reduces even more. Most activities have ceased - only more TVs than usual are running.	60 kW
4:45 (p.m.)	Half time	The demand rises almost instantaneously. Lights i.e. in the bathrooms are turned on, fridges are opened and meals are prepared.	180 kW
5:00 (p.m.)	Second half	The demand reduces significantly, because other activities have ceased.	60 kW
6:05 (p.m.)	End of extra time	There is a strong rise in the demand and from 18:15 on it is higher than usual. This is because in many households meals are cooked simultaneously and other activities are resumed.	180 kW
7:00 (p.m.)	After the game	The demand is expected to peak, because all postponed activities are resumed at the same time.	300 kW

Riddle 9: students use the red overhead transparency to find the correct wind turbine power curve (poster 2). Then they use the weather forecast on the website to estimate the wind speed at the given times (result of the riddle 7) and extract the yield of the turbine.



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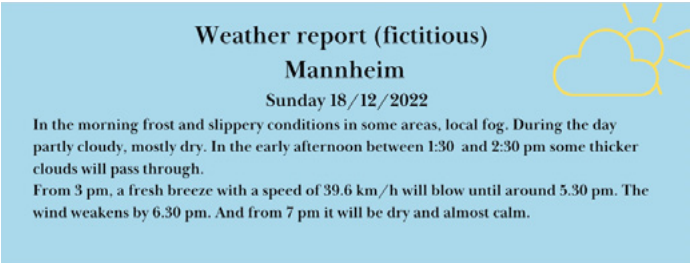
Riddle 10: the aim is to find out how much power the solar system delivers at the three given clock times (see result of riddle 7) using the chart expected yield of the photovoltaic (PV) unit, which has a gap (poster 2); the overhead transparency with the missing part of the curve (envelope 2); and the weather forecast on the website.



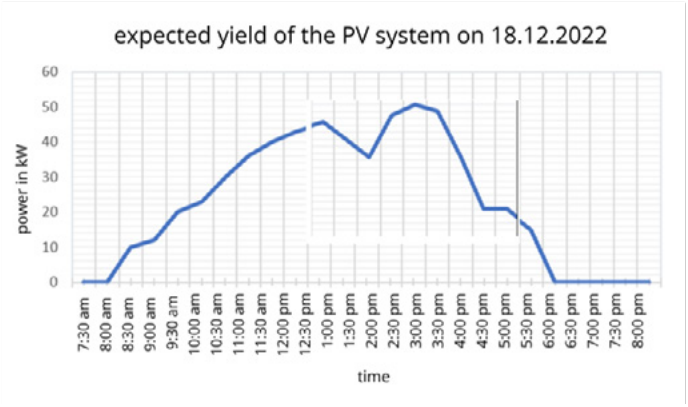


Image courtesy of the author

Riddle 11: students must use all the information collected to receive the code to open their combination lock by using the scratch program.

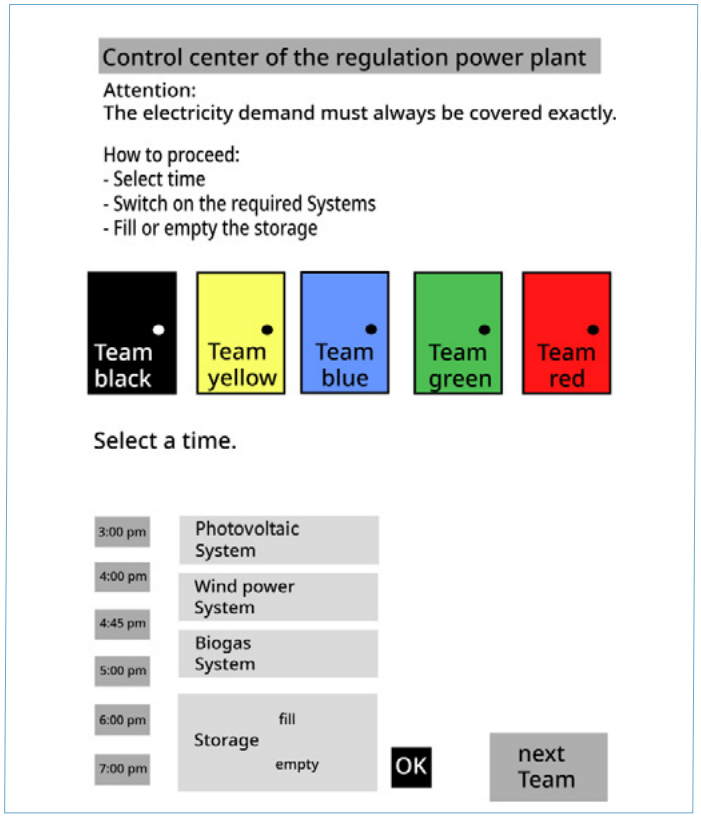


Image courtesy of the author

Materials

Per group:

- Puzzle 2 website (see QR code from puzzle 1)
- Poster 2 (A3 size) with tasks and riddles for part 2
- Envelope with:
  - set of 6 puzzle 2 power cards:
    2 Ω 60 kW, 1 Ω 80 kW, 2 Ω 180 kW, 1 Ω 300 kW
  - red-coloured overhead transparency
  - puzzle 2 transparency with a missing part of the curve
- Link to the HTML page of the Scratch program

Procedure

1. Distribute to each group the digital device and all materials needed for the second puzzle, so that they can continue the task.
2. Note: students have to solve riddle 7 first, as they need the results for the other riddles. They can then decide the order in which they solve riddles 8–10 before moving on to the final riddle.
3. The students solve puzzle 11 on the laptop provided by the teacher. The Scratch program is available to them for this purpose. Here, they have to deliver the right amount of energy at the given times (4:00 pm, 4:45 pm, and 7:00 pm). Consider if it makes sense to use the biogas

plant and if the energy storage is filled or empty. The results that the students have to enter in the program are shown in the table. As each group finishes, they can come to the box and open their lock.

4. When all locks have been opened, the key can be accessed, and the energy switch can go ahead! The students can then have the treats to celebrate.

Results

Riddle 7 gives the clock times (4:00 pm, 4:45 pm, and 7:00 pm) required for the other riddles. Riddles 8–10 then give additional information required to solve the final riddle. In riddle 11, students use the Scratch program and have to select which energy sources are available at the three given clock times, whether the biogas plant has to be switched on to cover the demand, and whether the storage tank is filled or emptied. If they have chosen all the results correctly, they receive a colour code, which they convert into a binary code and then convert into decimal numbers. With these numbers, they can open one combination lock. Please note that each group receives its own code, depending on the lock colour.

Time of day	Energy need	Energy PV unit	Energy wind turbine	Energy storage		Biogas plant
				fill	drain	
4:00	60 kWh	35 kWh	160 kWh	Yes	no	
4:45	180 kWh	20 kWh	160 kWh	no	no	
7:00	300 kWh	0	0	no	yes	use

Conclusion

As part of the educational escape game, students slip into the role of an employee of the Village of the Future company and solve a variety of puzzles and riddles. In doing so, they can playfully apply and deepen their skills on complex topics such as energy supply through renewable energies, grid load, and data evaluation in groups. In addition to the content-related skills, the game promotes a variety of 21st century skills.[1] The game can provide students with a motivating[2] and solution-oriented environment in which they can work independently and in a self-organized manner. Also, communication and cooperation skills are promoted.[1] Finding solutions and providing information takes place in both analogue and digital formats and combines a variety of approaches and tools.

Use of escape games in the classroom

It is important not to take an escape game as a self-runner or a panacea, even if researchers have already been able to show that gamification can have an influence on learning effectiveness.[3] Rather, it is very important to select or create the game appropriately for the target group. If it is too challenging or too demanding, the effectiveness of the game will be severely limited[1] Help cards and tips can be made available to aid weaker groups. Furthermore, it is important not to carry out the escape game as a loose component of the lesson, but to actively integrate it into the lesson through preparation and follow-up.

For the escape game Village of the Future, a few topics are suggested below that can be discussed in class after the game. Therefore, the content of the game can be followed up on:

- **Riddle 1:** different kinds of solar cells, mode of operation, manufacturing process, and the demand/usage of resources.
- **Riddle 2:** graphical representation of energy conversion and energy-transmission chains.
- **Riddle 7:** mode of operation of a biogas plant.
- **Riddle 8:** discuss the energy needs of households, single people, and the net load over the course of the day.
- **Riddle 9:** analyze the characteristic curves of different wind turbines, the quality of a building site, and the quality of the energy-supply system.
- **Riddle 11:** compare energy density and storage capacity (e.g., useful heat, latent heat).

«

References

[1] Avargil S (2022) Knowledge and skills of university students in chemistry-related departments as expressed in a specially designed escape-room. *Journal of Science Education and Technology* **31**: 680–690. doi: 10.1007/s10956-022-09986-9

[2] Alabdulaziz MS (2023) Escape rooms technology as a way of teaching mathematics to secondary school students. *Education and Information Technologies* **28**: 13459–13484. doi: 10.1007/s10639-023-11729-1

[3] Bai S, Hew KF, Huang B (2020) Does gamification improve student learning outcome? Evidence from a meta-analysis and synthesis of qualitative data in educational contexts. *Educational Research Review* **30**. doi: 10.1016/j.edurev.2020.100322

Resources

- All the activity resources are available online.
- Watch an engaging video that explores how QR codes work by building one out of black and white tiles.
- Discover how classes in Germany can borrow the game for a small fee.
- Use geometry to estimate the CO2 absorbed by a tree in the schoolyard: Schwarz A et al. (2024) How much carbon is locked in that tree? *Science in School* **67**.
- Use baker's yeast to demonstrate biofuel cells in the classroom: Grandrath R, Bohrmann-Linde C (2023) Simple biofuel cells: the superpower of baker's yeast. *Science in School* **66**.
- Build a solar cooker and learn about the thermoelectric effect with Peltier modules: Mancini P (2023) Cooking with sunlight and producing electricity using Peltier modules. *Science in School* **61**.
- Make chemistry practice fun with chemical card games: Johnson P (2024) Stealth learning – how chemical card games can improve student participation. *Science in School* **68**.
- Extract keratin from wool and learn about its use as a raw material for biobased products: Zambrotta M (2024) Extract value from wool waste: keratin and the circular economy. *Science in School* **69**.
- Find resources to bring the science of sustainability into the classroom: Philippsen M (2024) Sustainability in the classroom: teaching materials from Science on Stage. *Science in School* **66**.
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AUTHOR BIOGRAPHY

Soraya Cornelius is a chemistry and science teacher at a secondary school in Germany. As an external doctoral student with a doctoral scholarship from the German National Academic Foundation, she has been investigating the effectiveness of self-produced explanatory videos as part of the Bohrmann-Linde working group at the University of Wuppertal.

Dr Anke Neuhaus works at the TECHNOSEUM in Mannheim, one of the largest technology museums in Germany. She has been running the student lab there for 20 years; it is visited by more than 20 000 students every year. For the student lab, she has developed several escape games, which can be booked by school classes.