Learning Physics to Code and Coding to Learn Physics

Saadeddine Shehab

Maya Israel

Activities that integrate science and computer science may help middle school students learn science and engage in computational thinking. Below, we describe an activity that engages students in learning physics to code and in coding to learn physics. This activity needs around six teaching hours to complete and is suitable for middle school students (age 11 – 14). This activity can also be an extracurricular activity maybe for the school's computer science club.

The purpose of this activity is to help students learn about power and its units (Watt and Kilowatt Hour), and their everyday applications. It can also help students learn about the use of variables, functions, and conditionals when coding. During the activity, students are engaged in a SCRATCH-based project that allows them to create variables and use functions to write codes for a program that can be used to calculate the total monthly power (in kWh) that is required by a lamp and a computer to operate for a fixed number of hours each day. The project can also allow the students to use conditionals to write codes for the program, so it compares the total monthly power (in kWh) that is required by the lamp and the computer to operate for a fixed number of hours each day to the total monthly power supply, then makes a decision whether this supply is enough or not.

What is SCRATCH?

SCRATCH is an online computer program that can be used to code interactive stories, games, animations, and simulations (https://scratch.mit.edu/). To code in SCRATCH, students need to use different blocks to build a stack that can control the behaviour of different characters. In this activity, students will use the Events, Data, Sensing, Control and Operators blocks to write codes of a program that can calculate the total monthly power (in kWh) needed by a lamp and a computer to operate for a fixed number of hours each day and then compare it to the minimum power that a solar panel can supply in order to decide if the solar panel is able to supply the lamp and the computer with enough power to function.

Implementing the Activity

Materials. Projector, one personal computer per student

The problem. The SCRATCH Cat bought a new house in Urbana. In the house, he installed a lamp and a computer (see Figure 1). The power of the lamp is 200 Watts and that of the computer is 50 Watts. The Cat wants to use the lamp for an average of 17 hours a day and the computer for an average of 12 hours a day. To supply the lamp and the computer with power, the Cat installed a solar panel at the rooftop of the house. Since the Cat's house is located in Urbana, the maximum power that the solar panel can supply is 300 kWh/month (in July) and the minimum power that the solar panel can supply is 100 kWh/month (in December)

Will the solar panel that the Cat installed be able to supply the lamp and the computer with enough power to operate?

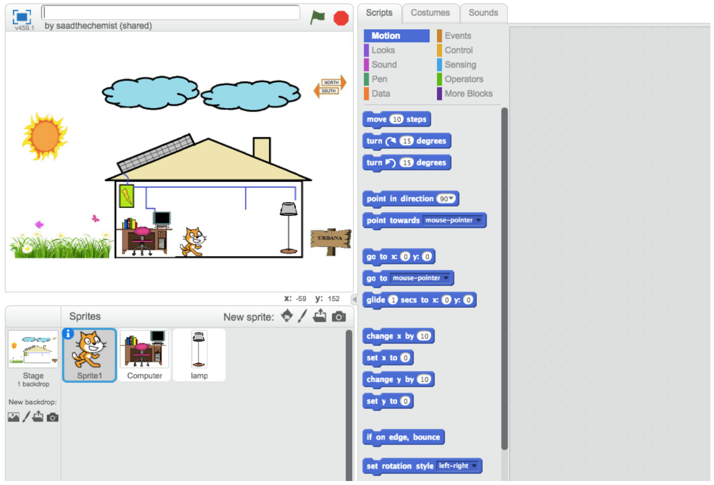

Figure 1

Instructional sequence.

Setting up the stage for implementing the activity. Before the beginning of the activity, the teacher distributes a copy of “the problem” to each student. The teacher can also project “the problem” on the white board if available. Then, the teacher can use the THINK-PAIR-SHARE strategy to engage students in interactions to discuss the following questions:

1) What does Power mean?
2) What does Watt mean?
3) What does kWh mean? What does kWh/month mean?
4) What is a solar panel? How does it work?
5) How does the location of the house influence the power that a solar panel can supply?

In order to facilitate the discussions that can lead to answers to the presented questions, the teacher can use the following YouTube videos:

https://www.youtube.com/watch?v=1__KjuGNzxc

https://www.youtube.com/watch?v=lmIGonMm9jk

https://www.youtube.com/watch?v=L5jpCY3BO4k

Devising a plan to solve the problem. After setting up the stage for implementing the activity, the teacher can put students in dyads or triads and instruct them to think about a plan to solve the problem. At this stage of the activity, the students are not required to run calculations. The teacher must emphasize that the purpose of the group work is to come up with a plan that can be later iterated to solve the problem.

After the group work activity, the teacher can facilitate a whole-class discussion that ends up with a common plan that all groups can iterate to solve the problem. One possible plan can be:

1) Calculate the power that the lamp needs to operate (in kWh/month)
2) Calculate the power that the computer needs to operate (in kWh/month)
3) Calculate the total power that the lamp and the computer need (in kWh/month)
4) Compare the total power that the lamp and the computer per month to the minimum power that the solar panel can supply

5) Decide if the solar panel that the Cat installed is able to supply the lamp and the computer with enough power to operate

Using SCRATCH to build a program that can iterate the plan.

Step 1. After devising a common plan to solve the problem, the teacher can ask the students to use their personal computers and go to https://scratch.mit.edu/. Then, the teacher directs the students to create Scratch accounts by clicking on "Join Scratch" then following the instructions.

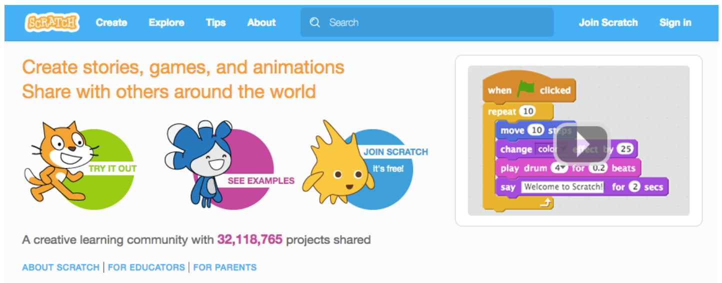

Figure 2

After creating a Scratch account, the teacher directs the students to search for the "Solar Panel Coding Stage One" project using the search box, click on the only project that appears, then click "See Inside". Figure 3 shows what students will see on their screens after clicking "See Inside".

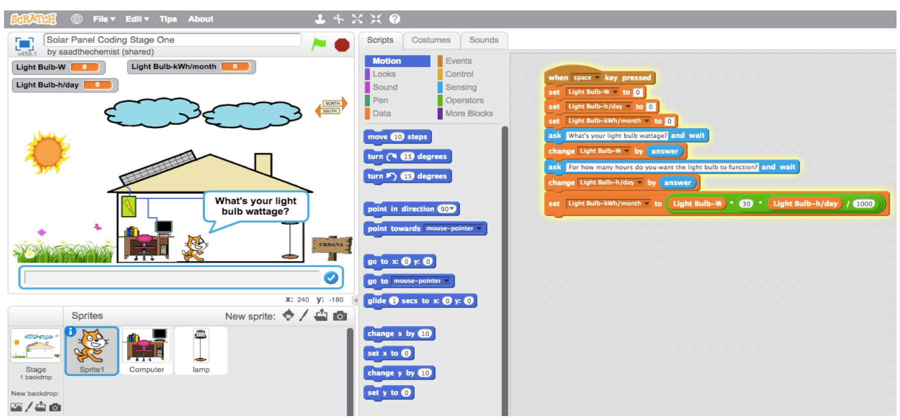

Figure 3

The teacher asks students to test and examine the written codes and their corresponding scripts. The teacher can use the THINK-PAIR-SHARE strategy to engage students in interactions to discuss the following questions:

1) What does each line of the written codes do?
2) What scripts were used to create each line of the written codes?
3) How are the written codes related to the common plan that was devised to solve the problem?

After the THINK-PAIR-SHARE activity, the teacher can facilitate a whole-class discussion to make sure that all students:

1) Understand the function of each line of the written codes

2) Understand how the scripts of the Events, Data, Sensing, and Operators categories were used to write the codes that allowed the program to calculate the power that the lamp needs to operate in kWh/month

Step 2. After understanding how the written codes were created and how they can allow the program to calculate the power that the lamp needs (in kWh/month) to operate, the teacher directs the students to work individually on their personal computers and use scripts to write additional codes that allow the program to calculate the power needed by the computer in kWh/month and calculate the total power needed by the lamp and the computer in kW/month. To do so, the students need to write codes that:

1) Ask the user to enter the power (in Watts) of the computer
2) Ask the user to enter the average time (in hours per day) for using the computer
3) Calculate the power that is needed by the computer per month in kWh
4) Calculate the total power needed by the lamp and the computer in kWh/month

As students work on writing their codes, the teacher must avoid giving direct answers to students' questions. The teacher must encourage students to leave their computers and seek help form their peers whenever they are stuck. The teacher directs the students to save their projects when the task is completed or when the time is up.

Figure 4 shows the codes for a program that can calculate the power needed by the lamp in kWh/month, the power needed by the computer in kWh/month, and the total power needed by the lamp and the computer in kW/month.

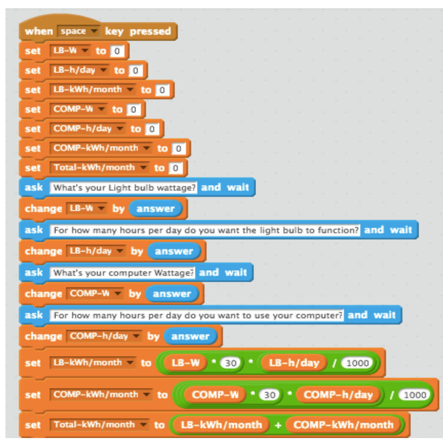

Figure 4

Step 3. The teacher directs the students to work individually on their personal computers and use scripts to write additional codes that allow the program to compare the total power needed by the lamp and the computer to the minimum power that the solar panel can supply, then decide if the solar panel that the Cat installed is able to supply the lamp and the computer with enough power to operate. To do so, the students need to write codes that:

1) Ask the user to enter the minimum power that a solar panel can produce in a specific month in kWh
2) Compare the total power needed by the lamp and the computer in kWh/month with the entered minimum power that a solar panel can produce a specific month in kWh, then:

- If the total power needed by the lamp and the computer in kWh/month is ***greater*** than the entered minimum power that a solar panel can produce in a specific month in kWh, the cat should say: "Oh no, my solar panel cannot supply my appliances".
- If total power needed by all appliances in kWh/month is ***less*** than the entered minimum power that a solar panel can produce in a specific month in kWh, the cat should say: "Yaay, my solar panel can supply my appliances".

As students work on writing their codes, the teacher must avoid giving direct answers to students' questions. The teacher must encourage students to leave their computers and seek help form their peers whenever they are stuck. The teacher directs the students to save their projects when the task is completed or when the time is up. Figure 5 shows the codes for a complete program.

Figure 5

This activity was implemented with 12 students in a technology classroom of a Midwest middle school at the USA. The preliminary analysis of the video recordings that were collected during the activity indicates that students were engaged in effective interactions around coding and relevant science concepts.