Computational thinking

BY SUSAN GERMAN

Students develop computational thinking by approaching new situations using a variety of computer-based methods, including simulation, data mining, networking, automated data collection, gaming, algorithmic reasoning, robotics, and programming. Computational thinking is different from mathematical thinking. According to Sneider et al. (2014), students develop mathematical thinking when they attempt to approach a new situation with their acquired math skills, including counting, arithmetic, algebra, geometry, calculus, set theory, and topology. Computational thinking is part of the *Next Generation Science Standards* science and engineering practices (see Figure 1). Computational thinking can be used in conjunction with any of the practices.

FIGURE 1: ***NGSS*** **SEP: Mathematical and Computational Thinking (NGSS Lead States 2013, Appendix F, p. 10).**

Mathematical and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.

- Use digital tools (e.g., computers) to analyze extensive data sets for patterns and trends.
- Use mathematical representations to describe and support scientific conclusions and design solutions.
- Create algorithms (a series of ordered steps) to solve a problem.
- Apply mathematical concepts and processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems.
- Use digital tools and mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem.

Implementing computational thinking

Computer simulations provide students with the opportunity to model phenomena by changing the input conditions and measuring the outcome. While I firmly believe it is best for students to interact with physical phenomena, a computer simulation can be more time efficient and allows students to try out “What if…?” scenarios in a safe manner. Computer simulations are best used in situations where physical phenomena are difficult to study directly, such as the solar system or molecular motion. However, while electric circuits are directly observable, using a simulation can bring the unobservable parts of the phenomenon to an observable level.

I developed an assessment on electric circuits after my students completed a unit on electricity, during which they learned about series and parallel circuits. The assessment used the PhET Circuit Construction Kit: DC-Virtual Lab (see Resources), which allowed students to virtually construct different types of circuits, adjust the number of resistors used, and add switches. Students studied and measured the current (amps) and voltage (volts) of the following circuits: simple (Figure 2), series (Figure 3), parallel (Figure 4), and complex (Figure 5).

While building circuits and measuring current and voltage, students asked, "Why are the charges moving slower in the series circuit than in the parallel circuit?" To determine that the chargers were moving slower, students chose to use an ammeter to measure the current of the circuit. When the ammeter measured lower amperage on wires where the charges moved slower, students were able to observe the current and build a mental model of electric current. Alternatively, students could work with a physical circuit and set up the series circuit and parallel circuit with light bulbs. Students would be able to observe differences in the brightness of the bulbs and make measurements of the voltage and current in each circuit; however, the actual movement of charge would be based on a student's inference. Using a computer simulation as a scientific model allows unseen parts of the circuit to be made visual.

To assess student understanding of series, parallel, and complex circuits, I asked them to build models of a circuit of a flashlight with three bulbs and specific design criteria. (Figure 6). In the simulation, students had access to a large voltage battery as well as a regular battery. While using a 100-V battery is beyond the norm of flashlight batteries, allowing students to use the battery forced students to think deeper in constructing a circuit. In order to solve the problem created by using a battery too large for a flashlight, student needed to add resistors in order for the circuit to properly work. (Students set a lot of simulation circuit fires as they worked on solutions.)

Conclusion

Computational thinking is more than using a computer simulation to make observations. This lesson required students to "use digital tools and mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem" (NGSS Lead States, Appendix F, 2013). My students used a simulation to explore their "What if…?" questions when they integrated the high-voltage battery as the energy source for their circuit and created a circuit that meets the requirements of the assessment.

Furthermore, the problem was engineering in nature. Students used a simulation to develop and test ideas for how well they met the defined criteria—a process made quicker by using a simulation rather than physical materials. The important step in the lesson is for students to understand that the simulation is programmed with algorithms based on data for how a physical circuit works and abstractions that allow students to visualize

FIGURE 2: Simple circuit

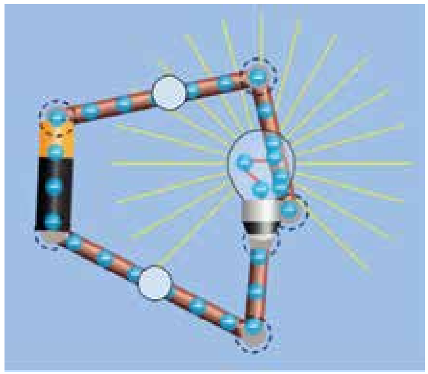


FIGURE 3: Series circuit

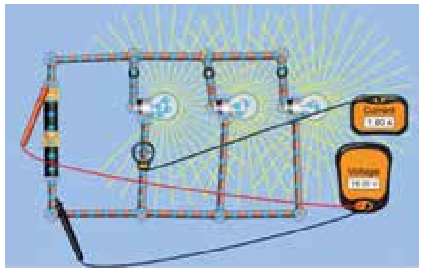


FIGURE 4: Parallel circuit

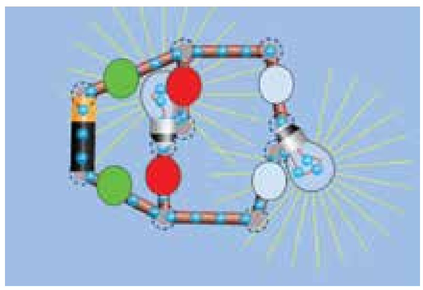
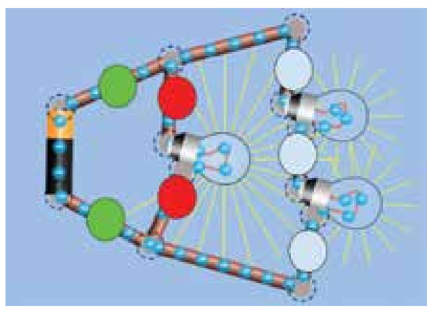


FIGURE 5: Complex circuit



the normally unseen portions of the phenomenon.

FIGURE 6: Flashlight problem

You want to create a flashlight using three bulbs. It will be essential to control which lights are turned on (one light, two lights, or three lights). You can use one or two batteries, no more than three switches, and as much wire as necessary. The flashlight design should maximize the brightness of the bulbs and be on one circuit.

Use the simulation we have been working with to come up with a circuit design.

- Screenshots of your final design
- A written explanation of your final design
  - Claim—a statement describing your final design
  - Evidence—data from investigation that supports your design
  - Reasoning—connect the evidence to claim by describing the science involved
- Data on your final design (voltage and current)

REFERENCES

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states*. Washington, DC: National Academies Press.

Sneider, C., C. Stephenson, B. Schafer, and L. Flick. 2014. Teachers Toolkit: Exploring the science framework and *NGSS*: Computational thinking in the science classroom. *Science Scope* 38 (03): 10–15.

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RESOURCE

Circuit simulation—*https://phet.colorado.edu/en/simulation/circuit-construction-kit-dc-virtual-lab*

Susan German (*sgerman@hallsville.org*) is a science teacher at Hallsville R-IV School District in Hallsville, Missouri.