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Design and build a smart lamp

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Help students develop STEAM skills by building a smart lamp with this creative project that combines physics, programming, and art and design.

Cross-curricular projects that combine science with art and technology offer a great opportunity to enhance students' creativity, which is a key 21st century skill.[1] We describe a project developed by teachers at Flatåsen School in Trondheim (Norway), where students design and build their own 'smart' lamps that are controlled by various sensors on a micro:bit (www.microbit.org).

This creative project combines knowledge of electric components and circuits with algorithmic thinking and programming, while enhancing students' skills in product design, project planning, and the use of selected crafting methods and tools. A smart lamp can have various shapes and functions (figure 1).

The project follows several design steps, interleaved with short booster courses that introduce students to required knowledge and skills as they need them [2]. In this way, we follow the ideas of integrated science, technology, engineering, arts, and mathematics (STEAM) teaching,[3] where school subjects are taught in a relevant cross-curricular context, rather than as isolated pieces of knowledge. Figure 2 shows an example of the progression from a sketch to the final product.

Figure 1: A smart lamp can have various shapes and functions.
Image courtesy of the authors

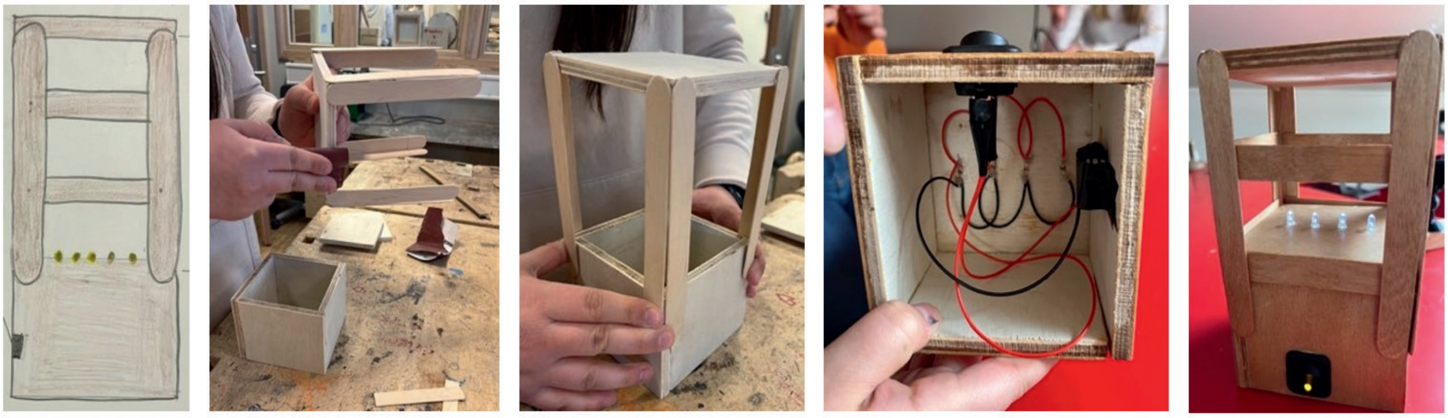

Figure 2: From design to final product
Image courtesy of the authors

The project was developed for students aged 13–16. We ran it over 7 weeks using teaching hours from science, mathematics, and arts & crafts. In total, approximately 35 hours were required. However, the time can be reduced by focusing on the technical part (electric circuits, sensors, and programming) or by limiting the choice of materials for making the lamp.

Safety note

Never directly connect (short-circuit) the 3V and GND pins on a micro:bit.

Activity 1: Get familiar with electric components

Through this activity, students gain practical experience with electric components available for use in their lamp designs. It is assumed that students have prior knowledge of basic electric circuit concepts, such as voltage, current, resistance, closed versus open circuit, and series versus parallel connections. The activity takes approximately 1 hour.

Materials

- micro:bit powered by a battery (one per student)
- Selection of light-emitting diodes (LEDs) of various colours
- Wires with alligator clips

Procedure

Guide students through the following tasks:

1. Make an electric circuit that lights up one LED. Use the 3V and GND pins of the micro:bit as the voltage source. Is it important which way we connect the LED?
2. Make an electric circuit that lights up two LEDs of the same colour. Should the LEDs be connected in series and parallel? Why?
3. Experiment with connecting two LEDs of different colours. Does the colour choice make any difference? Why?

Some of the connections are shown in figure 3.

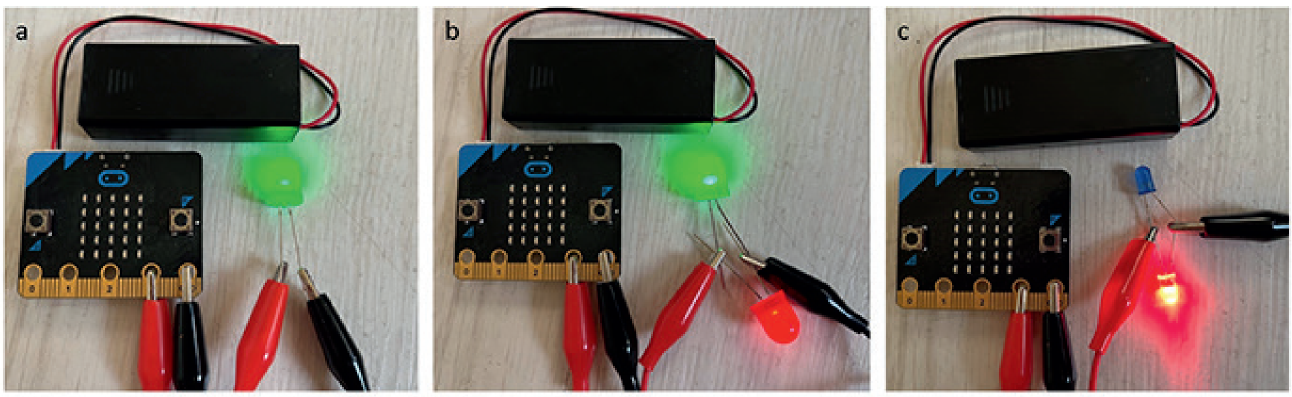

Figure 3: Experimenting with different LED connections
Image courtesy of the authors

Discussion

LEDs of different colours have different threshold voltages (1.6–4 V). If two LEDs with significantly different threshold voltages are connected in parallel, only the one with the lower threshold voltage will be lit (see figure 3c). However, some LEDs on the market have a built-in current-limiting resistor. Such LEDs can be connected in parallel, irrespective of the colour.

Activity 2: Explore smart functions

This activity guides students through different possibilities of controlling LEDs using micro:bit. It enables them to come up with smart function ideas for their lamps, e.g.

- turning on and off by handclaps
- turning on when it's dark and off when it's light
- remote-controlled lamp
- alarm-clock lamp

The micro:bit acts as a programmable switch that can turn LEDs on and off, or change their light intensity based on environmental light, sound, temperature, etc. Furthermore, LEDs can be controlled remotely in different ways using another micro:bit as a remote controller.

The online block-based editor MakeCode (makecode.microbit.org) is used to program the micro:bit. Students should have some prior knowledge of basic programming concepts (e.g. loops, logical expressions, variables) and some prior experience with programming the micro:bit by MakeCode. The activity takes approximately 2 hours.

Materials

- Computer (or tablet) for programming the micro:bit (one per student or student pair)
- micro:bit with USB cable (or battery) (one per student)
- Wires with alligator clips
- Selection of LEDs of various colours

Procedure

1. Show the students how to connect a LED to a micro:bit (figure 4a).
2. Introduce the functions 'digital write pin' and 'analog write pin' (Advanced → Pins). An example is shown in figure 4b.
3. Let students program the micro:bit to perform some of the following tasks:
   a. Turn a LED on and off using buttons A and B, respectively.
   b. Toggle a LED on/off using a single button.
   c. Make a LED blink on a left tilt.
   d. Turn the LED on when the light level is below a given threshold.
   e. Adjust the LED light intensity using buttons A and B.
   f. Control three LEDs to function as a traffic light or a disco lamp.
   Several code examples are provided in the supplementary material.
4. Give a short introduction to radio communication between two micro:bits and point to the main radio functions.
5. Let students program a remote-controlled LED in pairs. One student writes the transmitter code and the other the receiver code. An example is shown in figure 5. Make sure that each group uses a unique radio group number.

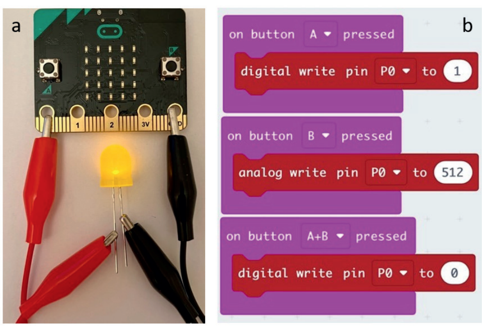

Figure 4: LED connection to micro:bit and the code to control it (full intensity/dimmed/off)
Image courtesy of the authors

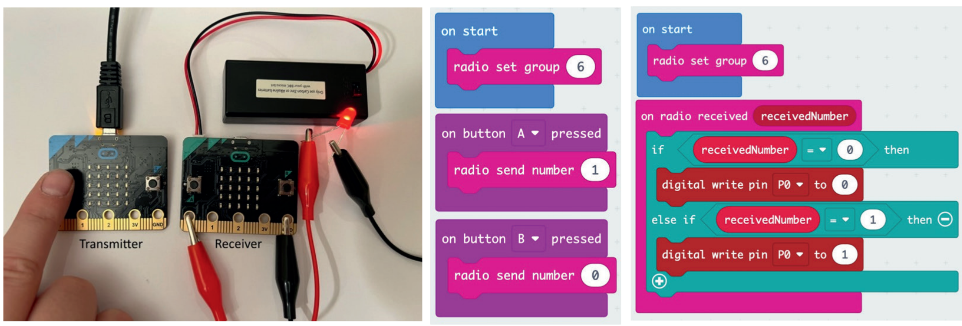

Figure 5: Remote-controlled LED with transmitter and receiver codes
Image courtesy of the authors

Activity 3: Design the smart lamp

In this activity, students are encouraged to develop their own lamp designs. This gives them a feeling of ownership and enhances their engagement. Ideally, 5–6 hours distributed over 2 weeks are needed to allow the idea to mature. This activity can run in parallel with the first two activities.

Materials

- Pen and paper

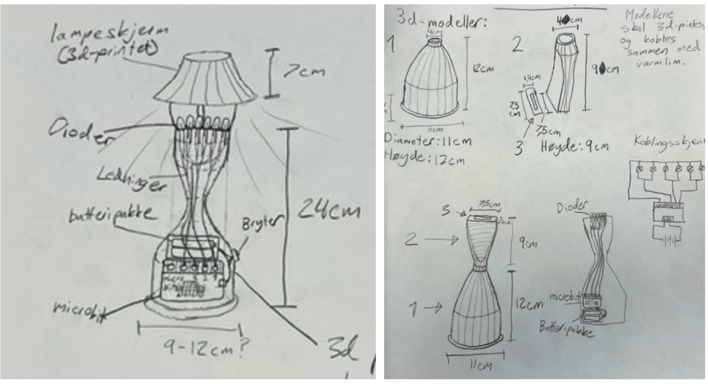

Figure 6: Construction drawing
Image courtesy of the authors

Procedure

1. Discussion: Let students consider various applications of smart lamps. Can they be useful for disabled people, or when it is too dark to see the switch? Can they improve sustainability by saving energy? What is the purpose of your smart lamp?
2. Brainstorming: Each student sketches at least three smart lamp ideas.
3. Design: Each student chooses one idea to develop further in detail and decides upon following aspects:
   a. How will my lamp look?
   b. Which materials will it be made of?
   c. What smart functions should it have to meet its purposes?
   d. How will electric components be integrated into design?
   This results in a construction drawing that includes the dimensions, required materials and tools, a circuit diagram, and a description of the smart functions. One example is shown in figure 6.
4. Review: The teacher approves the lamp designs based on the construction drawing and dialogue with the students.

Activity 4: Build and program the lamp

In this final activity, students build and program their smart lamps according to the construction drawing (see figure 7). This is the most time-consuming process, but also the most engaging as the students see their designs come to life. Approximately 20 hours distributed over 4 weeks should be planned for this activity.

Before starting to build, students can be offered short practical booster courses (Extension activity 1) to boost their skills in use of relevant tools.

Figure 7: Building the lamps
Image courtesy of the authors

Figure 8: Students' smart lamps showing a wide range of expression and variety of materials

Image courtesy of the authors

Materials

- Selection of building materials: cardboard, craft sticks, wood, wire, glue, paint, nails, screws
- Selection of electrical materials: LEDs of different colours, PVC-coated wires, batteries
- Selection of basic tools: hammer, drill, handsaw, chisel, screwdriver, glue gun, scissors, paintbrushes
- Computers (tablets) and micro:bits with USB cables

In addition, students can be offered optional tools and materials covered in the booster courses.

Procedure

Have students perform the following tasks:

1. Find appropriate materials: some are offered at school, while others can be found at home or in nature.
2. Build the lamp according to the construction drawing.
3. Connect the electrical parts according to the circuit diagram.
4. Make and test the program according to the selected smart functions.

Variation

The materials could be restricted to recycled/recyclable materials to focus on sustainability.

Discussion

Students should be given the opportunity to steer the project according to their interests. In our school, some students spent considerable time finding materials for their lamp at home or in nature, while others worked intensely on refining the smart functions of their lamp. Figure 8 illustrates a large variety of student products.

Summary

The smart-lamp project puts traditional science content in a modern setting. The open-ended task enhances students' creativity and offers valuable experience with problem-solving and time management. It can also be individually adapted to give all students the chance to succeed. The project both challenges and engages students to a high degree and gives them a great sense of ownership and achievement. It is nice to organize a viewing gallery (Extension activity 2) at the end of the project, where students get the chance to present their work.

This project requires collaboration between teachers of different subjects and a willingness to spend teaching time on cross-curricular projects that allow individual choice and in-depth work. It is a challenging project that requires a motivated coordinator. However, the payoff is providing students with meaningful and engaging science education that gives them insights into the importance of science in everyday life.

References

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[2] Norton S, Ritchie S M (2009) Teaching and learning science and mathematics through technology practice. In Jones A, de Vries M (eds) *International handbook of research and development in technology education* pp 419–429. Sense Publishers. ISBN: 9789087908775

[3] White D, Delaney S (2021) Full STEAM ahead, but who has the map for integration? – A PRISMA systematic review on the incorporation of interdisciplinary learning into schools *LUMAT: International Journal on Math, Science and Technology Education* 9: 9–32. doi: 10.31129/LUMAT.9.2.1387

Resources

- Find out about the micro:bit educational foundation
- Use Microsoft MakeCode for micro:bit
- Read about the environmental consequences of light pollution: Henshaw C (2022) Too much of a good thing – the problem of light pollution. *Science in School* **56**.
- Discover how chemistry and light interact in many aspects of our everyday life: Douglas P, Garley M (2010) Chemistry and light. *Science in School* **14**: 63–68.
- Build a rocket in your classroom: Rønningen J et al. (2012) Sky-high science: building rockets at school. *Science in School* **22**: 36–41.
- Teach students the conservation and transfer of energy with Rube Goldberg machines: Ferguson S et al. (2022) Conservation and transfer of energy: project-based learning with Rube Goldberg machines. *Science in School* **56**.
- Create an installation using old bicycle parts to demonstrate energy conversions: Martins Raposo-Weinberger P, Wardell S (2022) From cycling to upcycling: build creative installations from old bicycles to learn about energy conversions. *Science in School* **60**.
- Build a modulated laser based on a cheap, commercial laser pen: Bernardelli A (2010) Stage lights: physics and drama. *Science in School* **17**: 41–45.
- Read about creative approaches to recycling: Florean C (2018) Adventures in creative recycling. *Science in School* **45**: 27–30.

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Bojana Gajić, Nils Kristina Rossing, and **Berit Bungum** work on science education at the Norwegian University of Science and Technology. Eirik Lyngvær is a teacher at Flatåsen School in Trondheim, Norway, where the smart-lamp project was developed and tested. All authors work together on the KreTek project, where they develop and research how programming can be combined with students' creativity and subject learning in science and mathematics.