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A misty way to see convection currents

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Do air convection currents really move as they are drawn in textbook illustrations? Let's make invisible convection currents visible using mist.

Using science demonstrations to communicate scientific ideas is an age-old practice that remains effective today. While infographics can be useful for illustrating certain concepts or phenomena, they only happen on paper, unless one makes direct observations. This is where demonstrations can bring scientific concepts to life in the classroom, making them tangible and memorable for students.

Gas convection currents are difficult to visualize because, unlike coloured liquids, coloured gases are hazardous. A possible demonstration can be done using smoke from a small flame travelling through an air convection current setup.[1] In Activity 1, we describe an alternative method of visualizing convection currents using mist and an electrically powered heater. Due to the absence of open flames, the demonstration is safer and more accessible. The robustness of the setup allows one to explore beyond the curriculum content and move into scientific thinking. In Activity 2, students engage in the process of scientific inquiry by proposing experiments to test an explanation for the phenomenon seen in Activity 1.

The activities require the use of an air current visualizer, which should be constructed before the class.

Constructing the air current visualizer

The visualizer should be constructed before the class, as described below. More detailed assembly instructions can be found in the supporting material.

Materials

For a DIY humidifier

(one can also use a ready-made home-use humidifier.)

- Ultrasonic mist maker
- Rectangular plastic/glass container
- Small USB fan (5 V direct current (DC))
- Corrugated plastic board

For an enclosure with accessories

- Small electric heater (3 cm × 4 cm, 5 V DC, 60°C)
- Aluminium sheet (6 cm × 7 cm × 1 mm)
- Transparency (plastic) film (15 cm × 15 cm)
- Cardboard box
- Plastic sheet (area to match cardboard box)
- Black corrugated plastic boards
- Polyvinyl chloride (PVC) pipes and joints

The setup should be constructed as shown in figure 1.

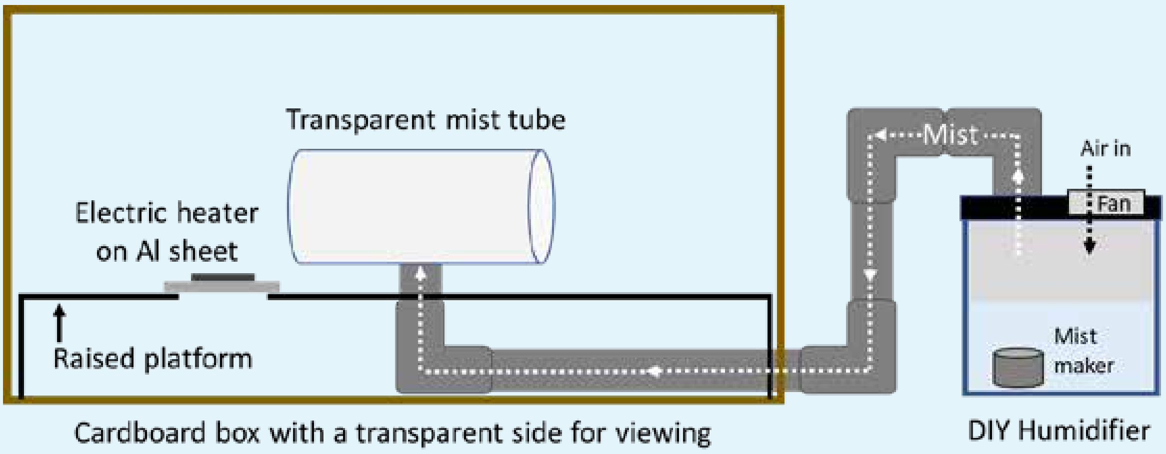

Figure 1: Schematic illustration of the demonstration setup
Image courtesy of the authors

Notes

1. Mist produced by the humidifier is channelled into the centre of a transparent mist tube via PVC pipes and joints.
2. To avoid interference from surrounding air, the mist is output into a cardboard box.
3. To create a viewing window, one side of the box is replaced with a transparent plastic sheet.
4. An electric heater secured on an aluminium sheet is positioned at the left mist output on a raised platform made from corrugated plastic board.

Activity 1: Visual demonstration of air convection currents

This activity can be performed as an in-class demonstration by a teacher introducing the concept of convection currents in air. The visualization of convection currents is captivating and enhances the joy of learning. Student engagement can be boosted with the predict, observe, and explain framework suggested below. The setup can be further used for scientific-inquiry-based discussions (Activity 2) and/or modified to illustrate how temperature differences can create wind, such as a sea breeze.

The target audience can range from ages 11 to 16. The demonstration will take 5–10 min. The setup takes an hour to build and optimize.

Materials

- Air current visualizer (constructed before the class)
- Water
- A 12 V DC source
- The observations worksheet

Safety notes

Potential burn and electrical hazards. Use a low-power electric heater (5 V DC) that does not go above 60°C. The mist maker used here requires a 12 V DC source. Use the adapter and read the instructions provided by the manufacturer. Use the mist maker only when it is fully submerged in water.

Procedure

1. Begin with the heater at room temperature (RT). Turn on the mist maker and fan. Regulate the amount of mist that goes into the transparent mist tube by covering the fan partially with a piece of card.
2. **Observe** the flow of mist.
3. Have students **explain** their observations.
4. Have students **predict** what will happen when the heater is switched on.
5. Turn on the heater and **observe** closely the changes to the flow of mist.
6. Ask the students to explain why the mist rises and relate the demonstration to the content they learn in class.

Results and discussion

When the heater is off and at RT, the mist flows symmetrically towards both sides of the transparent tube. Upon exiting the tube, the mist sinks to the bottom at both ends. This happens because mist is denser than air. At this point, the teacher may remind students that mist is not gaseous water vapour but very tiny liquid water droplets. These droplets help to visualize air currents.

Upon switching on the heater, we observe that the mist soon begins to rise. This happens because warm air near the heater rises, carrying the mist upwards with it. As it rises, the air loses heat and sinks back down after reaching a certain height. The cyclic movement of a fluid (such as air) due to temperature differences is known as a convection current.

Optional extension: although the activity is written here as a class demonstration, students can engage with this as a hands-on project, in which they construct the visualizer themselves with the equipment provided, tinker with it, and then follow through with the procedure as a whole-class activity.

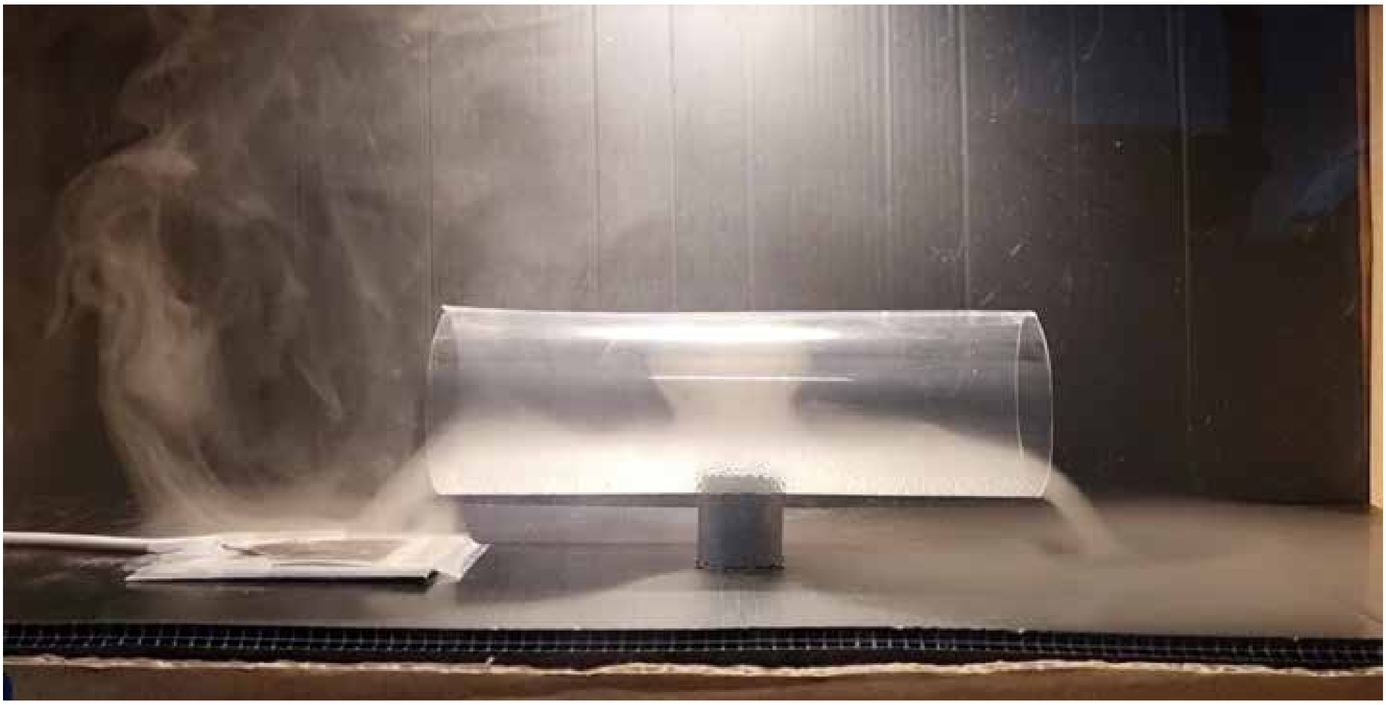

Figure 2: Using mist to show an air convection current. Mist enters the centre of a transparent tube and exits through open ends. An electric heater placed on the left-hand side heats up the surrounding air. The warm air rises, carrying the mist with it.
Image courtesy of the authors

Activity 2: Challenge a scientific explanation

Science education goes beyond teaching content. Students should also learn about how science progresses through the process of scientific inquiry. In this activity, students are presented with an alternative explanation for the phenomenon observed earlier. They propose experiments aimed at obtaining evidence to either support or falsify the explanation. Students work in groups to brainstorm ideas and draft an experimental proposal. It is helpful for the teacher to check in on each group and provide suggestions and formative feedback. After the students submit their proposals, the session can be wrapped up by demonstrating a simple experiment to test the alternative explanation.

The target audience can range from ages 14 to 16. Allow at least 20 min for group discussions. The demonstration to test the alternative explanation will take 5 min. The grading and feedback for each group's submission will take about 15 min.

Materials

- Setup used in Activity 1
- One A3 sized sheet of paper per group of students to draft and illustrate their proposals

Procedure

1. Recall the observation in Activity 1: mist rises from the (hot) heater. Demonstrate again if necessary.
2. Offer an alternative explanation: when the heater is hot, it emits radiation from its surface. The radiation pushes the mist, causing it to move upwards in this case.
3. Students get into groups to brainstorm ideas of how they can test this explanation. Write/illustrate their proposed experiments on A3 paper.
4. After the students submit their work, the teacher can demonstrate how one may test the alternative explanation. One possible way is:
   - Remove the transparent mist tube and reposition the heater such that it is upright and about 1 cm to the left of the mist outlet in the box.
   - Turn on the heater and humidifier. Regulate the mist flow so that the output is not too strong.
   - It is observed that the mist does not have a preferential motion to the right, thus falsifying the alternative explanation.
   - It is also observed that the mist near the heater rises high above the heater. This provides evidence to support the original explanation given in Activity 1.
5. After class, students are given feedback on their proposed experiments based on their validity and relevance.

Figure 3: Testing the explanation that mist is pushed away by radiation. As the heater is positioned vertically, most radiation from the heater moves horizontally to the right. Since the mist does not move preferentially to the right, the explanation is false. Additionally, we observe that the mist rises near the heater, supporting the original explanation of warm air rising, bringing the mist along with it.
Image courtesy of the authors

Results and discussion

This activity aims to immerse students in the process of scientific inquiry by having them design an experiment to collect evidence that can be used to judge a scientific explanation. As the task is probably unfamiliar to most students, it is advisable for the teacher to walk among the groups and provide feedback and guidance as needed. Advise the students to keep their proposals simple, feasible, and relevant, while encouraging creative ideas.

If students complete their experimental proposal well within the given time, they can be asked to predict the possible outcomes and provide corresponding interpretations.

For the demonstration shown at the end of the class, students may have to be guided along the flow of logic in interpreting the results. If the alternative explanation is true, then radiation from the heater will cause the mist to move to the right. However, it is observed that the mist does not move to the right; hence, the explanation is falsified.

Conclusion

It is important that science demonstrations are not just about theatrics and demonstrations of phenomena. A good demonstration should engage students with a minds-on experience to enhance learning. Asking students to predict a causal effect, make meaningful observations, explain phenomena, and propose experiments to test the explanations are ways to encourage scientific thinking while students watch the demonstration.

This activity provides an opportunity to engage students with the curriculum topics heat transfer (via convection), air currents, states of matter, density, and the scientific method. «

References

[1] A demonstration of convection currents using smoke: https://schoolscienceexperiments.com/convection-current-experiment-science-projects/

Resources

- Discover the capacity of gaseous water to start a fire.
- Read an article on how to run effective demonstrations in science lessons: Walsh E (2021) The art of science demonstration. *Science in School* **55**.
- Explore phase transitions between different states of matter: CERN (2021) States of matter & phase transitions. *Science in School* **51**.
- Try some classroom activities related to the thermal expansion of water: Ribeiro CI, Ahlgren O (2021) An ocean in the school lab: rising sea levels. *Science in School* **53**.
- Explore 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**.
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AUTHOR BIOGRAPHY

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