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i wonder...

Rediscovering School Science

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Place-based learning of science

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About Us

i wonder... is a science magazine for school teachers. Our aim is to feature writings that engage teachers (as well as parents, researchers and other interested adults) in a gentle, and hopefully reflective, dialogue about the many dimensions of teaching and lifelong learning of science in class and outside it. We welcome articles that offer critical perspectives on science and science education, a deeper exploration of the foundational concepts & underlying principles in the school science curriculum, and examples of practice that encourage the learning of science in more meaningful & inquiry-based ways. **i wonder...** is also a great read for students and science enthusiasts.

i wonder...
REDISCOVERING SCHOOL SCIENCE

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Editorial

Terms like climate change, global warming, ozone layer depletion, mass extinction and, now, the pandemic have become part of our everyday vocabulary.

Young people are exposed to these terms, not only in their school curricula, textbooks, and classrooms, but also as a flood of information and (mis)information from myriad sources – social media, TV etc. Researchers report how this has led to two contrasting impacts among children and young people. Anxiety and a sense of hopelessness on the one hand, and acceptance and indifference on the other. Both these conditions dent our ability to respond, as the physicist Fritjof Capra puts it, *"by cooperating with Nature's inherent ability to sustain life."* Building the ability to cut through this noise to understand scientific 'truth' is a first step. This would help, in science educator Jonathan Osborne's words, *"pupils emerge with an interest in science, a confidence to talk about it, and a willingness to engage with science wherever and whenever it crosses their paths."* Implicit in such learning is a comprehension of how nature sustains life – the web of intricate, interconnected relationships that afford resilience, and support the flourishing of human societies.

Science and scientific advances have provided us with newer ways of observing and understanding the earth's systems. While it allows us to be amazed by the beauty and wonders of life and natural phenomena, it also presents evidence of the profound planetary level changes resulting from human activity. Science is embedded in human society and thereby influenced by its changing priorities. It is also a process of constructive, collaborative inquiry, in and from diverse contexts. That is why science can help us arrive at coherent decisions and actions that sustain the web of life to lead lives as if the earth matters.

The seeds to inculcate such a spirit and practice of science are best sown at a young age. The school environment can be the earth in which to sow and nourish these seeds. Children need to explore the physics and chemistry of life and then bring them together with biological and mathematical principles. This way, they can learn to comprehend life and life processes as a systemic whole. Teachers can become the proverbial gardeners by teaching like the earth matters; creating and being part of learning experiences with children, sharing and rediscovering the world around us with curiosity, wonder, and empathy, while building sensitivity and awareness.

In this issue, many teachers share their explorations and experiences of teaching science like the earth matters. For example, Meenakshi Umesh presents compelling experiences of how viewing life as relationships where *"respecting the child, earth and the living world"* are at the core of science learning. Poornima and Nishant argue that observation-based learning, a critical aspect of scientific inquiry, and building relationships with the immediate environment make for meaningful learning. In contrast, Rohini Chintha uses an engaging conversation between a grandparent and grandchild to explore the role of individual actions in responding to environmental issues. Prashanth W and Kavita K connect children's real-world knowledge and experiences to classroom learning through their explorations of water as an essential for life.

What do you think of these experiences? What about your own experiences as teachers? Do share your feedback with us at iwonder@apu.edu.in.

Radha Gopalan
Editor

CONTENTS

PLACE-BASED LEARNING OF SCIENCE

POORNIMA ARUN & NISHANT

What is science, and what is its role in education? What kind of learning takes place when we give importance to relationships with place, people, and other beings? How do we balance immediate experience with pre-existing bookish knowledge?

"There are no unsacred places, only desecrated places" — Wendell Berry.

For the earth as a whole to matter, it is important for us to care for the place that we are in first. Our journey to reconnect with a place can be a long, ongoing process — collective and individual — of understanding, enjoying, and caring at deeper and deeper levels. This principle underlies a lot of the work at Marudam (see **Box 1**).

In terms of teaching, we don't always have ecology or earth-science as subjects, but all the class groups take time to build relationships with the natural landscape and its lifeforms. Some of these relationships are with the forests on the Arunachala hill nearby, some with the creatures in and around the school campus, with the surrounding village fields, with the plants that we eat, with the water that flows through the land and sits beneath it, and with the other people working in and around the campus (see **Fig. 1**). This process of reconnecting with nature is not an intellectual exercise, but one that emerges from experience, action, and reflection.

Relationships between people are as important as other relationships. If we acknowledge that we are all on a journey to reconnect with nature, then it becomes important for us to learn from and with each other. Teachers must also learn from those they teach because children often have keener senses and sensitivities. On the other hand, everyone, including children,

Box 1. An introduction to Marudam Farm School:

Marudam Farm School runs under the umbrella of The Forest Way — a registered non-profit charitable trust involved in education, afforestation, environmental education, organic farming, and more, near the town of Tiruvannamalai in Tamil Nadu. The journey of the school, the campus, and the land are the result of the passion and energy of several committed individuals, and the generous support of a large community of friends and donors from all over the world.

As of 2020, Marudam hosts some 130 children between the ages of 4 and 16 years; about 30 teachers and staff in different capacity; roughly 20 residents; numerous dogs, cats, cows, chickens; and a rich, diverse, and ever-growing wildlife population of all kinds. Located on an organic farm, and spread over 8 acres, land is something we constantly engage with as a rich, real-life, educational resource, integral to the learning process.

Being an immensely diverse group, originating from various cultural and social backgrounds, the richness of integration is a key element in our ethos. Working and learning closely together in such an environment, with very little formal structure, can be challenging at times. At the same time, it is endlessly enthralling, deeply rewarding, and never ever boring!

Fig. 1. Class in the Arunachala hill forest.
Credits: Marudam Farm School. Licence: CC-BY-NC.

must take responsibility for their own learning. In this sense, classes can be seen as ongoing agreements that are discussed and arrived at as a group. The fact that these relationships need time together is accounted for in setting timetables and the working rhythms of the school.

Seen from this lens, what is science and what is its place in education? As teachers engaging with science, how do we bring our own understanding to these questions?

Ground-up approach to learning science

The most positive aspects of science can begin with a child observing their surroundings, and asking about the how and why of different things around them. The child learns by engaging in open discussions about their observations, and connecting these to other things they have heard or read, including the body of knowledge that science has to offer. This process can start, for example, when a child asks how the fig tree *(Ficus mollis)* growing on a rock outcrop gets any nourishment at all. The child hears what their peers think. They discuss it together, connecting it to what they have read about roots and plant nutrition, as well as what they know about rocks, while being open to intuition. The teacher also participates in this discussion by asking questions or bringing other perspectives, but is careful about not taking over. This process can deepen each person's understanding and connection with the (amazing) fig tree, the rocks on the hill, their relationship with each other and their role in shaping the ecosystem. For this to happen, it's important that we allow some things to grow ground-up, starting from the child's experience and questions, rather than going top-down from the syllabus of a science textbook.

In fact, till middle-school, it makes sense to mostly focus on ground-up learning. To feed a child's natural curiosity, we expose them to different things around the neighbourhood and beyond. These include trips to other farms; landscapes like lakes and forests; structures like old houses, forts, temples with traditional architecture, craft centres; and other projects relating to alternate education and ecology. These are all a big part of learning in school, along with participating in the day-to-day activities of our own land. The children also spend half a day in every week of the academic year on the Arunachala hill. From middle-school onwards, there is an effort to gradually expose children to bits of the larger body of existing scientific knowledge, and connect these with their lived experiences to enrich their relationships. Learning science in this way brings together multiple perspectives — some to science, and others to the context in which it has evolved.

Bringing together multiple perspectives to science

A lot of scientific knowledge has been created with the assumption of human mastery over the earth. For example, science books often focus on the technical expertise involved in large-scale mining of ores and metals, widening of roads, harnessing of energy from rivers, the 'green' revolution, or the uses of forests. But they make no mention of the destructive impacts of these activities on the many webs of relationships in nature. In addition, some approaches to science can be very reductive. One example is of reducing a plant's complex interactions with soil to that of a mechanical pump-like uptake of water and mineral ions. This can help justify the use of chemical fertilizers without asking what they do to the countless relationships that exist between the plant and soil, or without acknowledging the experience of the soil actually being alive. These aspects of science have to be questioned as they come up. And they will definitely come up, because for children and adults who have a strong intimate understanding of plants, animals, and nature, these aspects are often jarring.

Going beyond questioning, we also have to integrate these as different perspectives. Often, it can seem as if science is the only systematic body of knowledge. This is seen, for example, in claims that modern biotechnology is an extension of, and an improvement over traditional agricultural knowledge, modern allopathy evolved from 'cruder' systems of traditional medicine, and modern civil engineering represents 'progress' beyond traditional structures. It is important to understand science, as found in textbooks, as just one form of knowledge. To recognise that emphasis on universal laws can often cause us to ignore the beautiful complexities in nature. That scientific knowledge can focus on reducing, manipulating, and extracting. But it can also increase our sense of wonder for and our connection to the earth, and can be used to have a healthy give-and-take with nature. That even though science has had a chequered history, it may still have a part to play in our onward journey to live harmoniously with the earth. Similarly, it is important to recognise that while traditional knowledge can help to hold up our intimate relationships with nature, it can sometimes lack some of the larger perspectives that we need to understand global phenomena. Also, it can get misrepresented and used in a wrong way or context. This is seen, for example, when people over-emphasise the benefits of some traditional food, or use herbal medicine as a simple substitute for allopathic practices. How can we get the best of both, or rather, all these worlds?

Building an understanding of context

Aside from bringing together multiple perspectives to science, it is also important to place science in its proper context. To do this, we often have to go into its history and sociology.

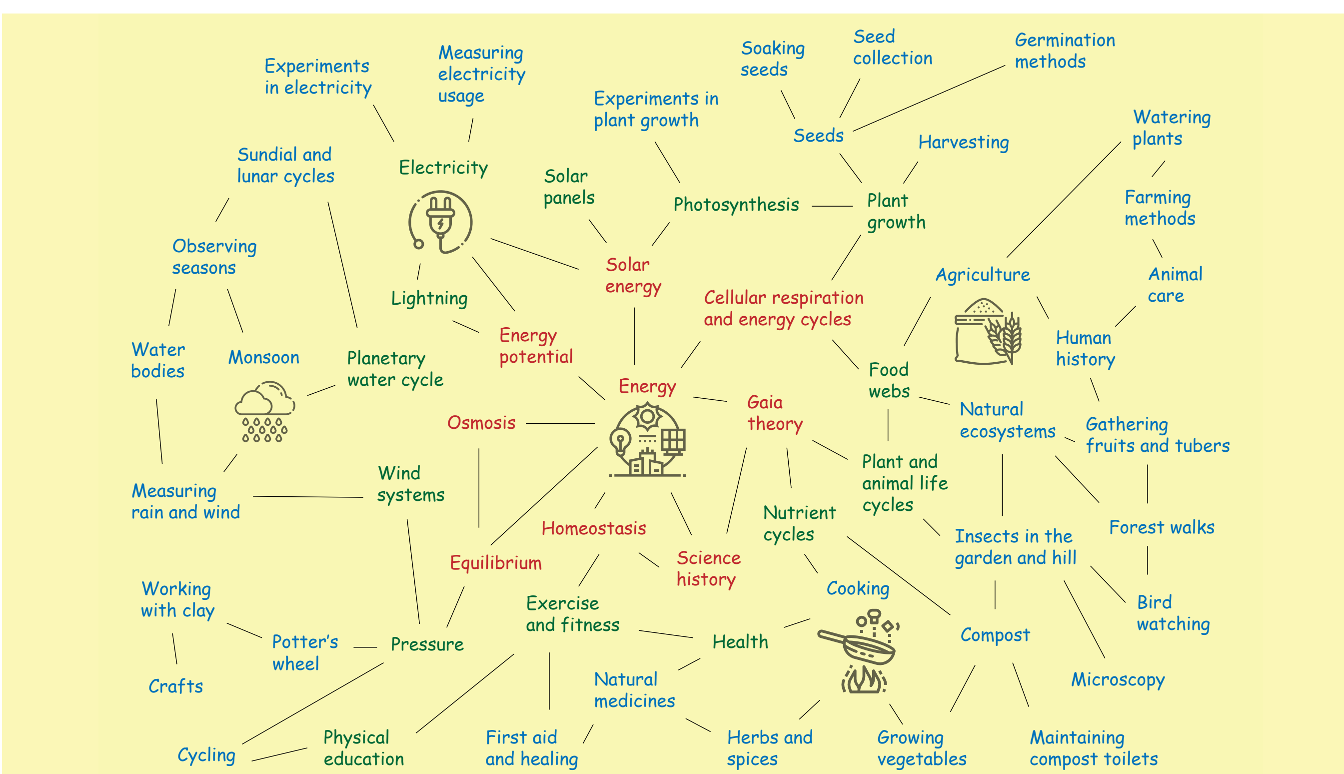


Fig. 2. Weaving a web of concepts. The concepts in red font in the center are more abstract concepts. Those in blue font, towards the edges, are activities. The ones in green build bridges between the ones in red and blue.

Credits: Marudam Farm School. Licence: CC-BY-NC.

Learning the historical context in which various discoveries were made or technologies were developed becomes important. To talk about the motivations and intentions of scientists and other contributors to this body of knowledge. To talk about and with people who hold other forms of knowledge. When we say in science that *'we're standing on the shoulders of giants'*, we often fail to appreciate that the giants are not in science but in indigenous systems of knowledge. For example, the sheer diversity of crops, which is the foundation for modern agriculture, was built through more than ten thousand years of local expertise. Similarly, much of our current pharmacological knowledge was derived from indigenous knowledge systems and practices. Interacting with practitioners of traditional and alternate systems can help us appreciate these things. For this reason, we often invite practitioners from diverse fields to share their perspectives with the school. These include ayurvedic and homeopathic doctors, allopathic doctors who are more conscious of their practice, wildlife conservationists, queer activists, architects practicing traditional and alternate methods of building, farmers using traditional varieties, organic farmers, and many others.

It is also important to continuously engage with the sociological context of science. For example, a discussion on the use of chemical fertilizers brought in by the 'green' revolution can involve many sociological threads. One thread is of how the Haber-Bosch process, which helps in artificially fixing nitrogen, came from advances in warfare. Another thread is about how the relationship between gut health and soil microorganisms is being underplayed in spite of confirmation from recent research. A third thread is of the current need for fertilizers given the growing world population, their diet, and the state of soil around the world. Related threads are of the importance of the soil tilth that many organic farmers consider central to plant growth, or the

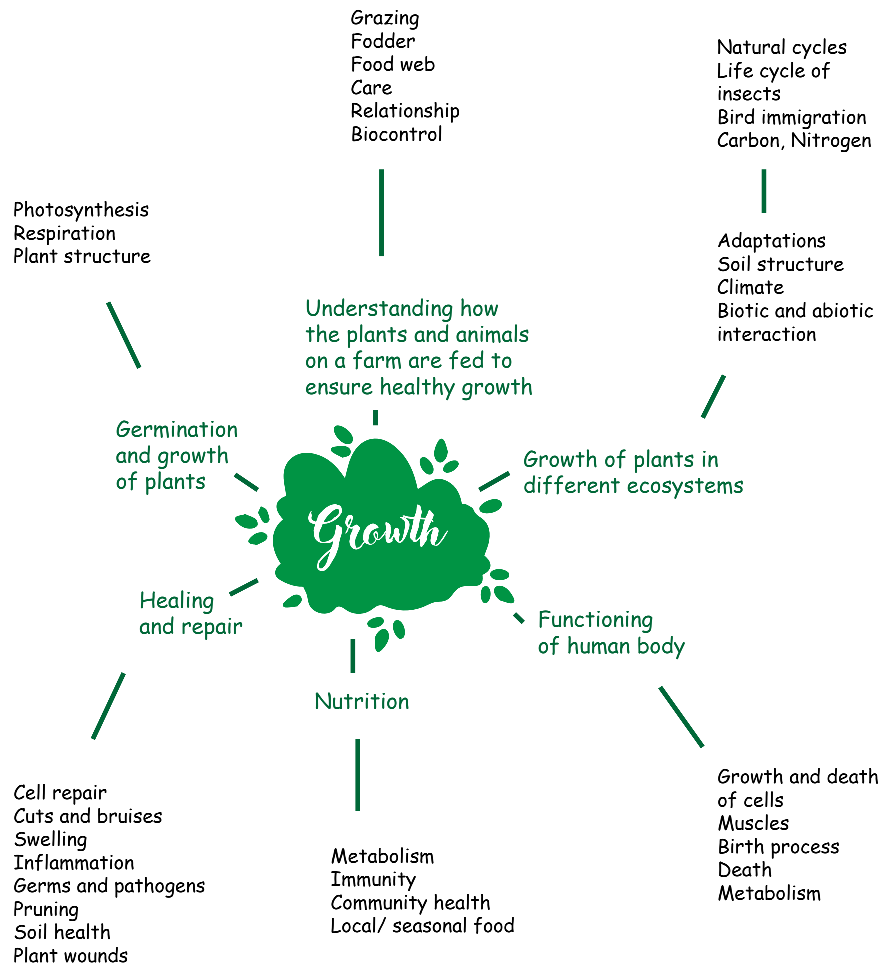


Fig. 3. This is what a concept map around growth may look like at Marudam. It is, of course, not possible to show all the interrelations between the concepts and activities, but a rough design is shown.

Credits: Marudam Farm School. Licence: CC-BY-NC.

experimentation with and rejection of chemical fertilisers by various indigenous people (like the Warlis of Maharashtra), and farmers (like Bhaskar Save). This, in turn, could lead to a discussion on the use of fertilizers in the neighbourhood, as well as interviews of local farmers and owners of agricultural shops.

Weaving a web of concepts

Aside from these issues of perspective, the sheer volume of the science syllabus can also be overwhelming. We have to be cautious not to dump concepts before there is a foundation of experience with which children can assimilate them. Also, since all the seemingly different divisions of science are actually interconnected and rest on each other, explaining almost any concept of science often brings up ten other concepts! For example, the idea of (cellular) respiration rests on the idea of chemical reactions, which rests on the idea of moles, valency, and bonds. This, in turn, depends on the Bohr model of the atom, and to appreciate this model, one needs to be familiar with radiation. This can continue almost endlessly. Parallelly, understanding cellular respiration also rests on the idea of cells. To understand this, one has to experience and understand microscopy, which rests on ideas in optics, which is connected to the properties of glass, and so on. Again, these connections are almost endless. Because of this web of interconnections, a child might take to science and begin a journey that gathers more and more momentum, or might not connect to its perspective and find it more and more contrived.

To address the problem of inter-related concepts all hanging in the air, it often helps to reorganise the syllabus. This can be done along themes that help us to draw from the rich experiences of a child in a particular place (see **Fig. 2**). A bridge concept, like the food-web for example, allows us to move across plants, our own bodies, agriculture, nutrient and energy cycles. But what we can't see fully is that these are in turn drawing from the rich experiences of children working in the garden and forest nurseries, helping with peanut, sesame and rice harvests, watering tree saplings, helping with cows, chickens, wild birds, and dogs, taking regular walks in the nearby forest or wilderness, picking wild fruit, using lenses and microscopes, observing insects and birds in the vegetable gardens, composting and maintaining compost toilets, helping in the kitchen for school lunch especially with salads, baking, and so on (see **Fig. 3**). If this ground work is in place, then more abstract concepts like gaia theory, energy, thermodynamics, equilibrium, cellular respiration can be approached. We can again use these central concepts to **build bridges** in other directions, like connecting the theme of 'energy' to the solar panels on top of the building, to measuring electricity flow in lights and fans, to measuring wind speeds and rain, to how cycles work, to the potter's wheel. Then come the big questions. For example, is this 'energy' really the **same** in all these contexts? What are the **differences?** Similarly, other central concepts like growth, or life-cycles, or body-movement, can be used to build bridges across a greater variety of experiences.

Parting thoughts

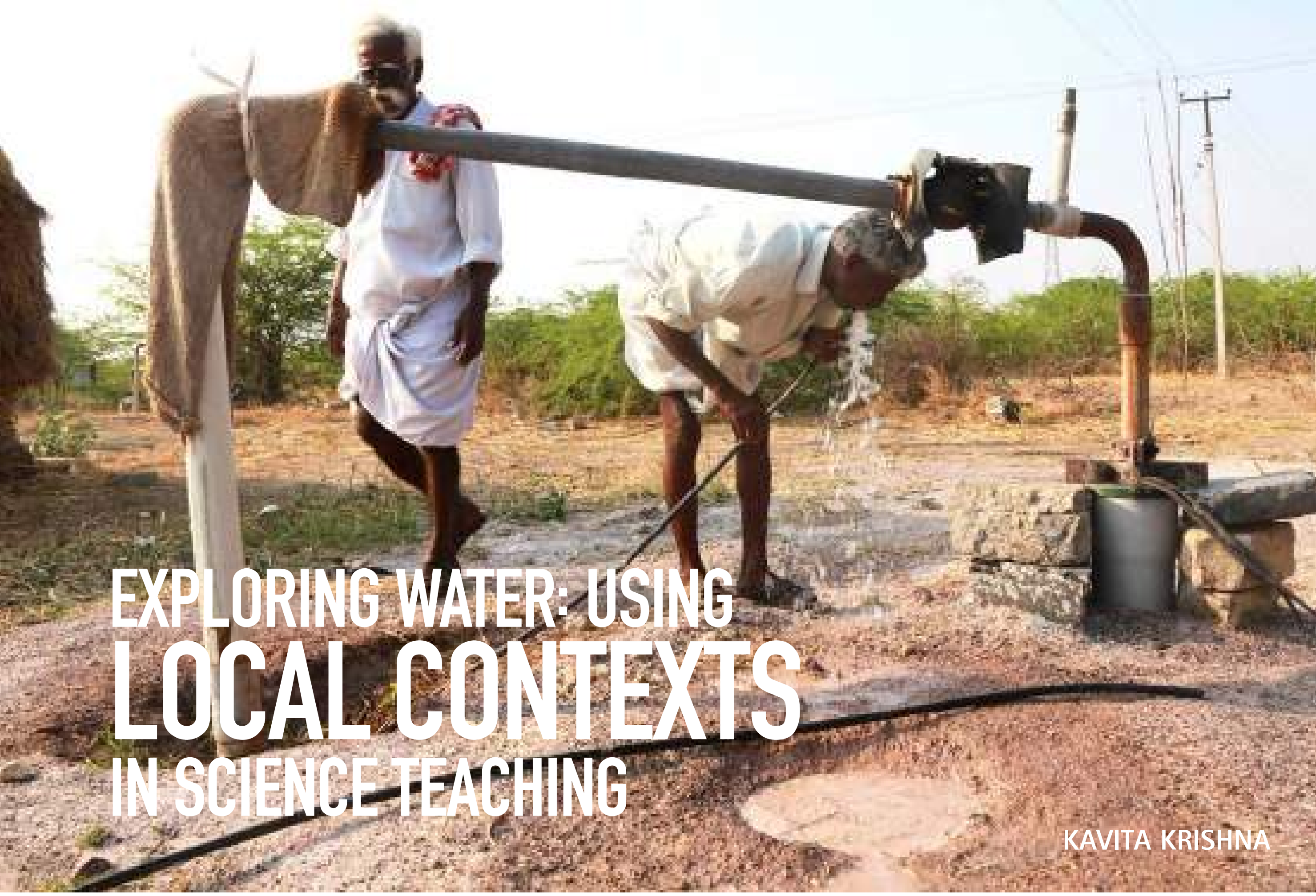
While we have tried to share some general approaches that are practised at Marudam, there is much more to share in terms of what we actually see in specific individual and collective learning journeys. Articulating these 'experiences of integration' has been an act of self-reflection for us, and will hopefully be interesting to other practitioners.

Key takeaways

- In terms of practice, there is always a question of what is universal and what is specific to a place. Perhaps it is important to be connected with one's local landscape and place-based knowledge, and evolve teaching practices along with it. So, if monsoons, ragi, and giant lakes are part of your landscape, and palm-leaf weaving, cow husbandry, and pottery are local skills, it makes sense to design teaching around these.
- It is important to explore science-based knowledge in the correct context — in terms of its history and politics, as well as in terms of each child's innate intuition. This is so that science is in service of wholesome learning instead of acting as a dominant system of knowledge that children must submit their intuitions to.
- Finally, the more bridges we build between experience and concepts, the more coherent academic learning can be. For this, experiences have to be rich, and time must be given for bridge-building.

Poornima Arun is a founder member and Head teacher of the Marudam Farm School, which started in 2009 with 20 children and has around 120 children now. She is involved in all aspects of running the school, from curriculum development to teacher training and administration. She has also conducted the annual craft week at Marudam for eight years now, in which traditional crafts people and artisans from all over come and teach these skills to children from various schools. She has been an active member of the Alternative Education Network for the past seven years, and was instrumental in starting a Tamil Nadu chapter three years back.

Nishant has been learning to teach for a few years now, mostly in Marudam, and over the summers at Marpha Foundation in Nepal. His interest in science is balanced by an equal interest in gardening and forests. He is constantly challenged by the process of bringing these together as group learning experiences. He also has a deep interest in practices of harmonious living, especially in the context of community life, to the extent that he is able to understand them.



EXPLORING WATER: USING LOCAL CONTEXTS IN SCIENCE TEACHING

KAVITA KRISHNA

'Water' as a theme offers many opportunities to learn basic science concepts, and study natural phenomena. But how do we help children connect this theme with personal experiences and pressing environmental issues? This article describes an attempt to do this in a rural middle-school classroom.

Teaching science to energetic 11- and 12-year-olds presents teachers with both a challenge and an opportunity. The syllabus[1] may tell us what they should learn, but how do we bring it to life? How do we teach children to apply science to explore natural phenomena? How do we help them connect a topic in the textbook with their local environment?

These questions underpinned my approach (see **Unit Plan Sheet**) to exploring the theme of 'water' over a period of five weeks in a school located in a drought-prone district of Andhra Pradesh. My students came from the surrounding villages and hamlets. Their parents were marginal farmers, pastoralists, or ran small rural businesses. Most of these children were the first generation to have progressed to middle school in their communities. Like many rural areas in India, these local communities had an intimate knowledge of their natural environment coupled with low levels of formal science education.

Learning in the classroom

I began by reviewing water-related concepts that students had learnt earlier. For example, my students had studied about mixtures and solutions, and investigated the solubility of different substances in earlier lessons. They had also used different methods to separate water from mixtures, and learnt about capillary action. In addition, they had learnt about the three states of matter (solid, liquid and gas), and had observed transpiration in plants (see **Fig. 1**). A review of what they already knew provided a good starting point for studying the water cycle and water quality.

We explored the water cycle through classroom discussions and demonstrations. Learning about precipitation, evaporation, transpiration, and percolation led to a discussion on how water constantly changes its 'state' and moves around the planet.

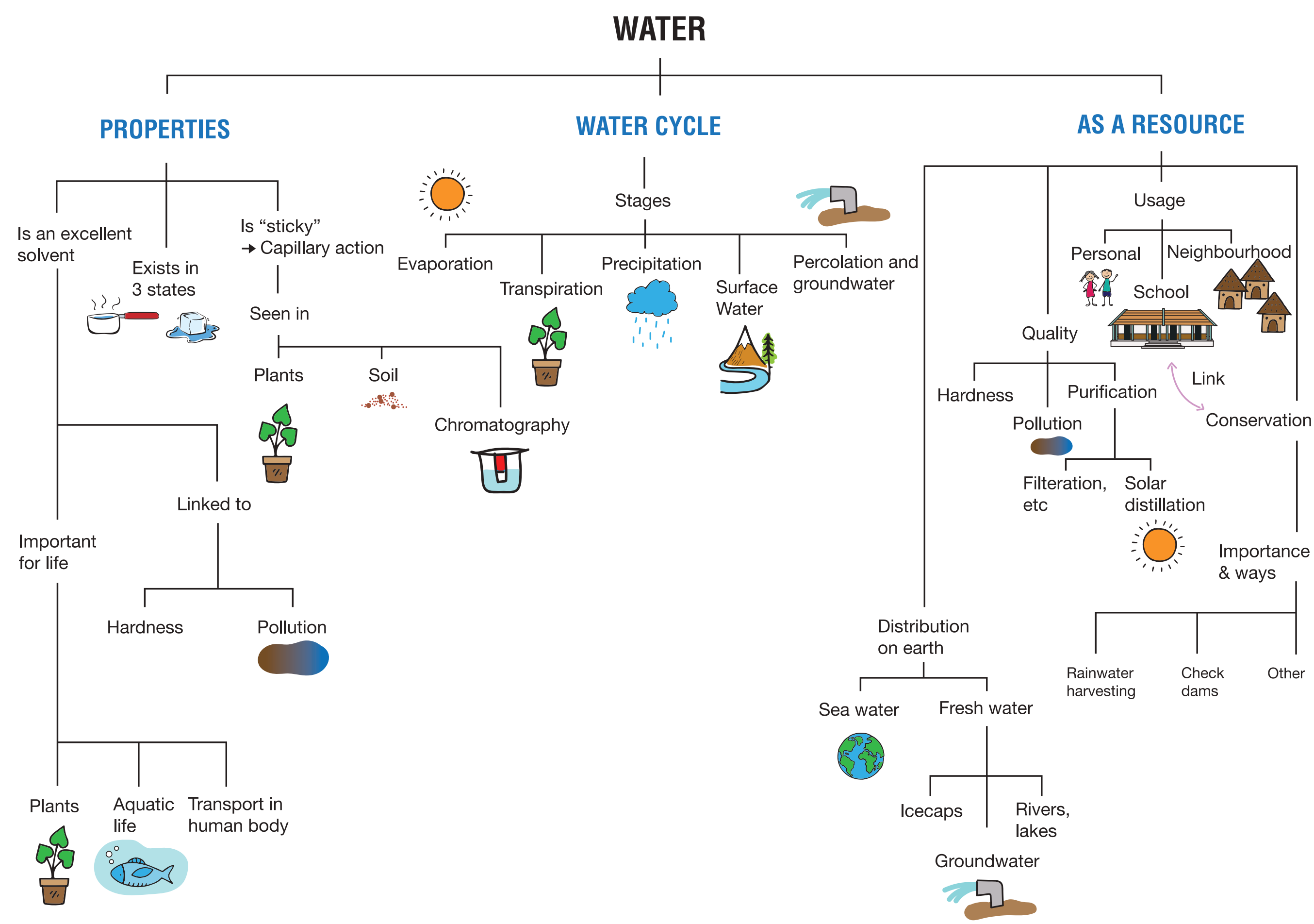


Fig. 1. A concept map for 'water'. A concept map can help a teacher see connections in the curriculum. It can also assist with planning lessons around a theme. This concept map for water helped plan this unit.

The concept of percolation then led to a discussion on groundwater — the main source of water in the region. Students were aware of how local communities and livelihoods were stressed by falling groundwater levels. I used a simple model to demonstrate how water percolates through the soil, collects in aquifers, and is pumped out of borewells (see **Box 1**). This sparked off a lively discussion on groundwater, with students raising questions like: *"Why do we find groundwater only in some places and not in others? Does a water diviner know where to find water? How deep does the water flow underground — is it like an ocean underneath? Why do we have to dig deeper to find water in borewells each year?"*

Another familiar and relevant aspect that we discussed was water quality. Most of my students had heard their elders referring to the increasing levels of 'salt' in water. They had also observed white deposits on vessels used to boil water. They could now understand that the water from borewells was a mixture of several substances. A demonstration to show that soap lathered more with distilled water (soft water) than with borewell water (hard water) led to a discussion on water hardness. We constructed a simple solar water distiller to observe how salts and other impurities could be separated from water.

Some students also raised questions related to water 'ownership' and rights, like: *"If our neighbour pumps too much water from his borewell, will ours dry up? How can we share groundwater fairly?"* This led to discussions about how water was used in each of their villages, as well as community management and conservation of water sources.

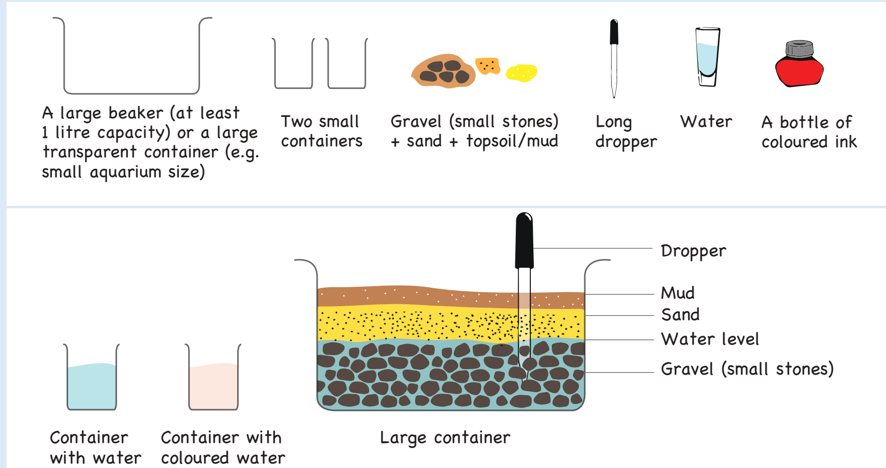
Learning from the community

Since we lived in a drought-prone area, we had all experienced water scarcity in very personal and immediate ways. Investigating local water sources, their usage and conservation was a natural extension to what we had discussed in the classroom.

As a first task, each student maintained a personal log of their water consumption (see **Activity Sheet I**). They recorded how much water they had used for different

Box 1. Making a simple groundwater model:

A simple model can be used to explain the source of groundwater and how it collects in the aquifer. This model can be used to demonstrate how borewells draw water from the aquifer, and that groundwater is a shared resource. It can also be used to show how pollutants contaminate aquifers, and discuss ways to conserve and recharge groundwater.



Making the groundwater model.

You will need

- A large beaker (at least 1 litre capacity) or a large transparent container
- Two small containers
- Long dropper
- Gravel (small stones), sand and topsoil or mud
- Coloured ink
- Water

How to build the model

1. Take the large transparent container and put a layer of gravel about 7-8 cm deep at the bottom.
2. Pour some water over the gravel till its level is about 2 cm from the base of the container. This represents groundwater.
3. Put the long dropper or straw into the gravel with its opening submerged in the water.
4. Pour a layer of sand over the gravel layer to about 4 cm depth. Make sure that the dropper stays vertical.
5. Add a layer of topsoil over the layer of sand to about 2 cm thickness.
6. In this model, the water and stones in the lowest layer represent the aquifer. The sand and soil represent the upper layers of soil through which the water percolates. The dropper represents a borewell. The base of the container and the table on which the container stands represent the bedrock.
7. Keep a small container of plain water ready. This will be used to represent surface water from rain.
8. Add a few drops of ink to another small container of water. Keep this colored water ready. This will be used to represent pollutants.

Explaining what an aquifer is

This step involves pointing out the different layers of soil in the model and explaining what each part of the model represents (students may be familiar with this if they have studied about soil). For example, in the model:

- The top layer represents the topsoil. This is the fertile layer in which you see grass and small plants growing.
- The layers of small rocks and sand in the model represent the permeable layers of weathered rock under the topsoil. The roots of big trees may reach these layers. These layers have spaces that can hold the rainwater as it percolates through them. The body of water held in this layer of soil and rock is called an **aquifer**. This is where we extract our groundwater from.
- The base of the container represents the bedrock, which is an impermeable layer of rock. Water cannot percolate through the bedrock.
- The dropper represents a borewell.

Demonstrating how groundwater is extracted from a borewell

Use a dropper to draw out some water. When you pump water out of a borewell, you are extracting groundwater from the aquifer.

Demonstrating how aquifers are recharged by surface water

- Demonstrate how groundwater is recharged. Gently pour some clear water from the beaker onto the top layer in the model without disturbing the layer. Let students observe how the water level in the aquifer goes up as the water percolates down.
- Discuss how rainwater soaks through the layers of soil and reaches the aquifer. This is called **recharge**. It can take time for the water to percolate and for the level in the aquifer to increase. The aquifer can also get recharged from water seeping in from streams, rivers, and tanks in the area.

Demonstrating contamination of the aquifer

- Demonstrate how pollutants can contaminate the aquifer. The coloured water represents pollutants like industrial effluents or pesticides. Pour some of the coloured water onto the surface without disturbing the soil. Wait for the coloured water to percolate into the aquifer (in the model) and draw students' attention to how the colour of water in the aquifer changes.
- Explain how pollutants on the surface can percolate into the groundwater and contaminate it. Pollutants can include effluents from factories, pesticides and fertilizers used on farms, and sewage from homes.

Questions for discussion

- Why do borewells go dry?
- Is groundwater a limited or unlimited resource? Why?
- How can we help to recharge the aquifer? Do you know of any attempts to recharge the aquifer in your neighbourhood?
- How can we conserve and manage groundwater?
- Do you think there are pollutants contaminating groundwater in your neighbourhood? If yes, what are the sources of the pollutants?
- What could be the effects of contaminated groundwater?
- Can we clean up groundwater easily once it is contaminated? Why?

purposes over a day, and compared their consumption with their classmates. This made them more aware of how they used (or wasted!) water, and ways in which they could conserve it. Next, we did a basic 'water survey' in the school (see **Box 2**). We investigated where the school's water supply came from, where it was stored, and how much was used every day. Students were fascinated by a new rain water harvesting system that was being built in the school. This provided a great opportunity to discuss different ways of collecting and storing rainwater in the community.

The idea of doing a 'water survey' was extended to their communities. The students, who came from several different villages, worked in groups and created 'water maps' showing water sources like borewells, surface wells, percolation tanks, and streams in their villages. They recorded water storage and distribution facilities like the village overhead tanks and community water taps (see **Fig. 2**). They also interviewed their grandparents and village elders to find out how the sources and usage of water had changed over time.

Back in the classroom, students were invited to share their findings. Many students were surprised to discover that there were no borewells when their grandparents were young. They learnt about local streams and ponds that had dried up. They heard about ways in which water was managed and shared as a community resource by earlier generations, and were able to contrast this with the current private ownership of borewells in their villages. Through conversations with their elders, they learnt of how the cultivation of water-intensive crops like paddy had replaced once-popular rain-fed grains like millets. This led to a deeper discussion of the many ways in which the advent of borewells had changed farming practices, and how water scarcity was affecting farming and livelihoods in their own villages.

Box 2. Surveying water usage:

The first essential step in managing water resources effectively is to understand how we use water. Researching and analyzing information about how water is used can help students become more aware of the importance of water conservation.

In addition to looking at personal water usage, students can gather information about water usage at the community level. Here are some activities that students can do, with some adult assistance, in their school and neighbourhoods:

School water survey

Students can investigate water usage in the school in different ways:

- Students could work in small groups to investigate different aspects of water usage like supply, storage, and conservation. They can do this by exploring water facilities like storage tanks, rainwater harvesting systems, and water meters around the school, and interviewing relevant staff members. They can then share their findings with the whole class.
- Alternatively, you could invite staff who manage the school water supply to the classroom for an interaction with students about water supply, use, and storage.

Students can find answers to questions like:

1. What are the different purposes for which water is used in school?
2. How much water is used in the school every day?
3. What is the source of the water? Are there different sources?
4. Is water purified before it is used? If yes, what are the ways in which it is purified?
5. Where is water stored? How much water can be stored in school?
6. Are any water conservation methods used in school? What are they?
7. Can we think of other ways of conserving water in school?

Neighbourhood water survey

Students can conduct a local water survey to understand how water is supplied, used, and conserved in their own neighbourhoods. Depending on their context, their neighbourhood may be a village, a few streets in a town, or an apartment complex in a city. They can do this by exploring water facilities (like wells, borewells, storage tanks, water treatment systems, rainwater harvesting systems, etc.) and interviewing adults. They could share their findings with the whole class by making a chart or a presentation.

Students can find answers to questions like:

1. What are the different ways that water is used in your village/ neighbourhood? List them.
2. Where do you get the water in the house from (a tap, a village well etc.)?
3. Do you have different water sources for different purposes e.g., drinking water, water for use in the home, water for use in the garden/farm etc.? List them.
4. If water comes in a pipe or a tanker, do you know where the water originates from (from groundwater, a river, a tank, etc.)?
5. Do you have to pay for water? Who do you pay? How much does it cost?
6. Are there storage tanks in your neighbourhood? If yes, how much water can they store? How often are they filled? Who is in charge of managing them?
7. Do you treat or purify water at home before it is used? If yes, how is it treated?
8. Is the water treated or purified before it reaches your home? Who purifies it?
9. Are any water conservation methods used? What are they?
10. Can you think of other ways of conserving water in your neighbourhood?
11. Talk to some elders and find out how water availability and usage have changed in the neighbourhood over the past few decades.

UNIT PLAN FOR WATER

This unit plan gives a brief overview of how the theme of 'Water' was covered over a period of five weeks with students of Grade VII. The emphasis was on contextualizing the NCERT curriculum to students' lives and the local environment by using familiar and relevant activities and examples. Links to concepts learnt in other topics were also reviewed and highlighted.

CONCEPTS COVERED	TEACHING - LEARNING ACTIVITIES	NOTES
Reviewing basic properties of water: • Water is an excellent solvent. • Water exists in three states — solid, liquid, and gas — all of which are commonly seen around us.	• Discussion using familiar examples. • Classroom demonstration of evaporation and condensation.	• Linked to concepts in 'Mixtures and Solutions' studied in 6th grade. • Linked to concepts in 'States of Matter' studied in 6th grade.
Water as a solvent: • Water's ability to dissolve substances is essential for life. • This property is also responsible for hard water. • Many harmful substances dissolve in water and are responsible for water contamination.	Discussion using familiar examples: • Blood, sap in plants, oxygen in water for aquatic life.	• Linked to concepts in 'Transport in plants' studied earlier. • Linked to concepts in 'Circulation' that is to be studied later in the year.
Capillary action: • Water can creep upwards through tiny spaces between solid particles	• Activity — doing chromatography using paper or chalk to observe capillary action. • Discussing familiar examples where capillary action can be observed.	• Linked to concepts in 'Transport in plants' and 'Soil' studied earlier.
The water cycle: • Water is constantly moving around and changing its physical state on earth.	• Explanation of the stages in the water cycle using illustrations.	• Linked to concept of transpiration from leaves studied earlier.
Water distribution and availability: • Freshwater vs. seawater. • Freshwater distribution globally, nationally, and locally.	• Discussion using maps and charts of global and national water distribution. • Demonstration to show relative amounts of water available as freshwater, groundwater etc.	

CONCEPTS COVERED	TEACHING - LEARNING ACTIVITIES	NOTES
Local water source — Groundwater • Where the water in borewells comes from — what an aquifer is. • Recharge of the aquifer. • Groundwater contamination.	• Demonstration using a groundwater model. • Discussion about local groundwater sources.	• Discussion can be extended to the 'ownership' and sharing of groundwater.
Water quality: • Water hardness. • Water pollution.	• Demonstration to show the difference between hard and soft water using soap. • Discussion about water pollution including local examples.	
Water purification: • Ways to purify water for domestic use.	• Discussing ways water can be purified — filtration, boiling, and distillation. • Constructing a simple solar water distiller.	• Linked to concepts in 'Separating Mixtures' studied in 6th grade.
Water conservation: • Importance of conserving water. • Ways to conserve water.	• Discussion about drip irrigation, rainwater harvesting, check dams and percolation tanks.	• As an extension, students interviewed their elders to find out about current and past water usage and conservation in their villages. • Students initiated a project to create a kitchen garden in the school to reuse 'grey water'.
Understanding our water consumption: • Personal water usage. • Water usage in the school and community.	• Estimating and recording daily personal water consumption. • Surveying water usage in the school. • Researching water distribution and usage in the village.	• Students learnt to measure, estimate, collect and record data in this activity. • Students interviewed school staff about water procurement, storage and usage in the school. • Students created 'Water maps' of their village to identify water sources, water storage and water distribution facilities.

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Fig. 2. Examples of children's village water maps.

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The discussion about changing water use patterns, water distribution, and water scarcity in their villages extended to a discussion about similar issues across the country and the world. For example, we used maps to locate sources of freshwater in India, discussed why it was becoming scarce, and considered ways in which it could be conserved and managed.

From learning to action

While water usage was being studied in the classroom, we began to look for more ways to conserve water on the school campus. Creating a kitchen garden to reuse the relatively clean water from washing or bathing (called **greywater**) appealed to the class. After scouting around the school for accessible sources of greywater, we decided to reuse the waste water from washing hands and vessels in the dining hall. A plastic pipe was laid to redirect this greywater to a small plot nearby. Students and teachers spent several evenings clearing the plot, preparing the soil, and digging channels to distribute the water (see **Fig. 3**).

Students formed small groups, each of which took responsibility for individual vegetable beds. They decided what to grow in their beds, brought seeds from home, planted the seeds, and tended their beds with enthusiasm. After every meal, they would run to check that 'their' plants got water. After a few initial arguments, they negotiated ways to 'share' the greywater fairly using a system of ingenious 'dams' and channels that they constructed.

The kitchen garden became the site for many lively discussions about water, soil, plants, and agricultural practices. Students asked questions, shared their observations and knowledge. For example, a student wondered whether the roasted dhania (coriander) seeds he had brought from home would sprout. This led to a discussion about seeds, and how they grow. Some students wanted to spray their plants with pesticides, while others objected and preferred to 'share' the fruits of their labour with insects and birds. Each encounter in the garden was an opportunity to explore and learn new ideas from each other.

While my students were thrilled to harvest vegetables, and contribute them to the school kitchen for their midday meal; I was pleased to see them developing greater initiative, responsibility, and cooperation. It was satisfying to see a child who struggled with reading in the classroom take the lead in the garden, or to listen to a timid child talk confidently about agriculture. The project provided a space for these children to develop skills and interests that were not possible inside a classroom.

Fig. 3. Rural school kitchen garden
Credits: Kavita Krishna. License: CC-BY-NC.

Benefits of this approach

Using a teaching approach that integrated different types of activities kept students enthusiastic and motivated. It offered them the opportunity to develop different skills, and to learn in a variety of ways. For example, some of them enjoyed reading texts related to these activities, while others contributed through their skill at model making. Some took the lead in gardening, while others contributed actively to classroom discussions. Thus, the diversity of activities made for a more inclusive learning environment.

Using the local community and context as a resource helped enrich learning in innumerable ways. Rural students were able to recognize and value connections between their own experiences, school science, and larger environmental issues. Learning science in this way allowed them to go beyond textbook-mandated knowledge and to systematically explore the local environment. Children learned about indigenous water-management practices from village elders, and were able to link this to contemporary issues. Their enthusiasm to go beyond the curriculum, and to take action to conserve water was an unexpected benefit.

The outcomes of this unit went beyond the 'marks' that the mandatory 'unit test' revealed about student learning. Students continued to engage with the ideas they had explored in class in practical and tangible ways. They were more mindful of their water usage in school, and could often be seen chiding younger children for 'wasting' water. The school kitchen garden continued to be the site of enthusiastic activity and discussions. Subsequently, students and other teachers went on to establish additional small garden plots at other wastewater outlets around the school.

Box 3. Some additional resources for teaching and learning about water:

- An offshoot of the India water portal with ideas for students and teachers: https://schools.indiawaterportal.org/
- A wealth of teaching resources about water from the US Geological Survey: https://www.usgs.gov/special-topic/water-science-school/science/teachers-resources-water-education?qt-science_center_objects=0#qt-science_center_objects
- A collection of simple, low-cost activities related to water: https://www.arvindguptatoys.com/air-and-water.php

Challenges and suggestions

Teaching a topic that included many activities, designed for inside and outside the classroom, presented several challenges. It took time to plan the curriculum, gather resources, and organize activities (see **Box 3**). Using an approach that encouraged students to explore each of these ideas took more time compared to that needed for a purely textbook-based one. Some prior planning, and the support of colleagues and students played a key role in making this experiential approach possible.

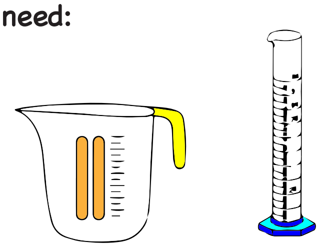
I was fortunate to teach in a school that was able and willing to give teachers and students the time and opportunity to explore this approach. In schools where it's not possible to spare the time or the resources to try such an approach, other simpler ways could be used to connect interesting and locally relevant activities with the classroom teaching of science. For example, activities linked to the topics being studied in class can be given to students to explore as part of their homework. Science clubs or science fairs in schools could be used as opportunities to initiate projects which explore these topics in deeper, and more multifaceted ways. The benefits of such an approach are well-worth the effort.

ACTIVITY I: HOW MUCH WATER DO I USE?

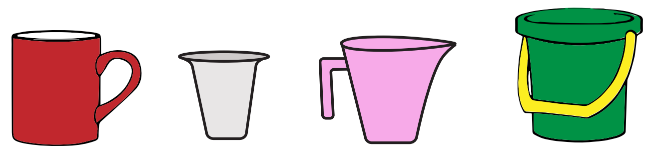
Aim:

Do you know how much water you use for different purposes every day? In this activity you can record and estimate the volume of water you use for different activities at home in a single day. ('Estimating' means finding a value that is close enough to the right answer by measuring, calculating, and thinking.)

What you need:



A measuring cup or cylinder (or any container with which you can measure volumes)



Some typical containers you use at home, like a cup/glass used for drinking, or a mug/ bucket in the bathroom etc

What to do:

(a) Using household containers to measure water quantity (volume)

To estimate your water usage, you first need to know the volumes of typical household containers that you use. Once you know their volumes, you can use these containers to measure how much water you need for different activities. This will help you estimate your total daily water usage.

Use the measuring cup or cylinder to find out how much water each of the following containers can hold when it is full. (Make sure you are not wasting the water you use to measure the volumes of these containers!)

1. A glass (or cup) I use for drinking holds ______________________ ml.
2. A mug I use for bathing and washing holds ______________________ ml.
3. A bucket I use for bathing and washing holds ______________________ mugs of water.
4. This is equal to ______________ litres.

(Multiply the volume of one mugful by the number of mugs of water used to fill the bucket. Remember, 1000 ml = 1 litre)

(b) Measuring your water consumption for a day

Think of all the ways you use water in a day. A few uses are listed below. Are there other activities you can add to the list?

1.	Drinking	2.	Brushing your teeth
3.	Washing face, hands etc.	4.	Bathing
5.	Flushing the toilet	6.	
7.		8.	

Use one of the containers whose volume you measured earlier to keep track of how much water you use for each activity. For example, use water from a mug when you need to wash your hands and note down how many mugs of water you use. Note down the number in the table below. Use an appropriate container to do this every time you use water during the day.

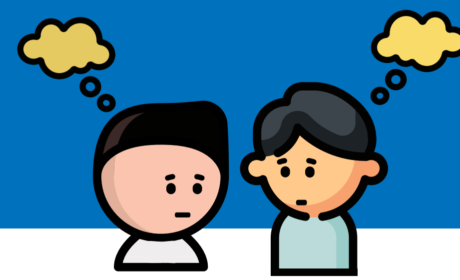
Record:

Fill in the table below every time you use water. You can add more activities to the table if you need to.

Purpose	Measured with	Number of full containers of water used (You can use tally marks here)	Total quantity used (Multiply the total number of full containers of water with the volume of the container)
Drinking	Glass with volume		
Washing and cleaning	Mug with volume		
Bathing	Mug with volume		
Flushing the toilet	Bucket* with volume		

(*If you use a flush, you can estimate or find out the volume of the flush tank. If you don't know you can assume a flush tank releases 6 litres of water.)

THINK ABOUT



At the end of the day, use the information you have filled in the table to answer the questions below. Remember, you need to measure, estimate or calculate to find the answers.

1. How much water did you drink?

2. How much water did you use for bathing?

3. How much water did you use for washing and cleaning yourself (hands, teeth, etc)?

4. How much water did you use to flush the toilet?

5. Which of these activities consumed the most water?

6. Which consumed the least?

7. Were you surprised by any of the answers?

8. Do you think you used more or less water in the day because you were measuring the quantities compared to a day when you don't measure your water usage?

9. Think of some ways you could reduce your water consumption (while keeping yourself and your surroundings clean and healthy!).

10. List any other ways you used water in the day for which you were unable to measure the water you used. Can you estimate the quantity of water you used for each task?

11. What are the other purposes for which water is used in your home? Here are a few suggestions. Can you think of more?
    1. Cooking
    2. Dishwashing
    3. Washing clothes

DISCUSS

1. What did you use the most water for? What did you use the least water for? Compare this with a few others in your class. In what ways is your water usage the same? In what ways is it different?

2. Compare how much water you use in a day with that of your whole class.
   - You can make a graph to show the results.
   - You can calculate the average water consumption for a student in your class. Did you use more or less than the average?

3. What are the ways in which you can conserve water in your daily life?

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Key takeaways

- The study of basic science concepts, natural phenomena, and environmental issues can be integrated in the theme of 'water' in middle school.
- Using the local context as a resource for learning enables children to see connections between their own experiences, science, and environmental issues.
- Including diverse activities in the local environment offers children the opportunity for enthusiastic and motivated engagement in practical action.

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Note: Source of the image used in the background of the article title: Memories of water Credits: Rahul M. and Sahith M, People's Archive of Rural India. URL: https://ruralindiaonline.org/en/articles/memories-of-water/.

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1. NCERT (2006), 'Syllabus for classes at the elementary Level - Volume 1', New Delhi.

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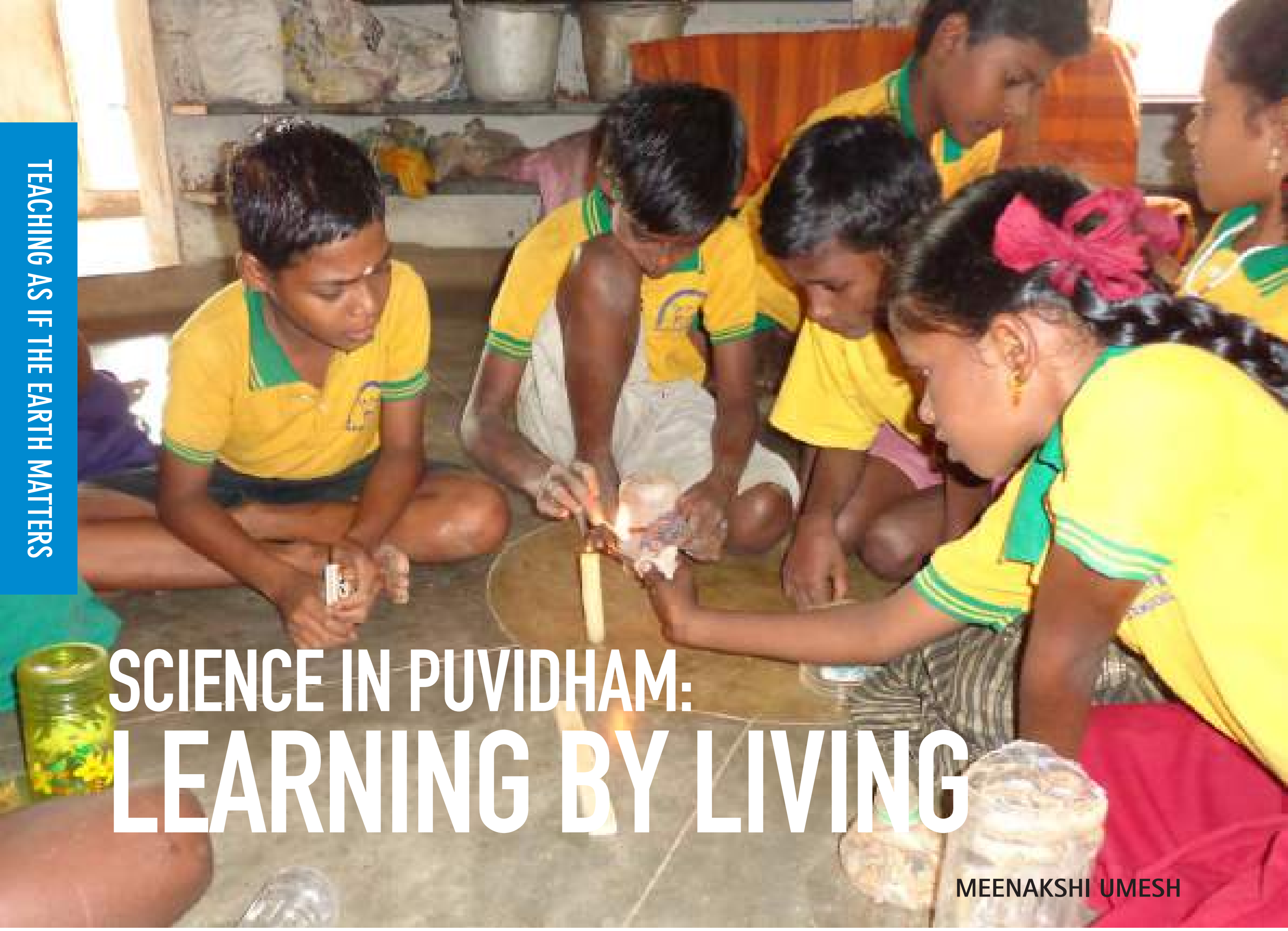

SCIENCE IN PUVIDHAM: LEARNING BY LIVING

MEENAKSHI UMESH

***Puvidham* means 'love for earth' in Tamil. At the Puvidham Learning Centre, children learn intuitively by observing, exploring, and working in their natural environment. How does this approach influence the learning of science? What role do adults, like teachers, play in this process?**

Science developed as a process of logical deduction of unknown facts from observed phenomena. Today, however, it is often taught within the closed environment of classrooms. Often, children are not offered time for observation, or the opportunity to connect textbook concepts with their own real-world experiences. What if children were to learn science through everyday explorations of their natural environment?

Connecting head and hands

At Puvidham, we explore scientific concepts through the work we do in and around the school (see **Box 1**). For example, all the maintenance work at Puvidham is done by the teachers with the help of the children. We also grow our own vegetables, cook our own meals, and make our own snacks. This involvement with the many activities of everyday life provides both children and adults with many opportunities to observe natural phenomena. For example, tending to our garden involves the use of a crowbar for digging, pruning shears for harvesting, and pulleys and pedal pumps for lifting water (see **Fig. 1**). Having used these implements, children are able to engage with a lesson on simple machines in practical ways, making the concept and related formulae easy to remember. Similarly, any malfunction in the pedal pump, which each child operates for 10 minutes every day to lift enough water to fill our overhead tank, provides the opportunity to find out what has gone wrong with it. Through their struggle to identify the problem, children develop a practical understanding of how pumps work in general. Activities like

Box 1. The philosophical core of Puvidham Learning Centre:

There is no learning without the desire to learn. Learning is an instinct. A child learns by observing the environment, and the events, processes, and individual players therein. Children do not learn what we teach, they learn what we live. A teacher inspires by their way of life. Thus, all adults in Puvidham adhere to the philosophy of respecting the child, the earth, and the living world. Their way of life conforms to their love for earth. This includes their commitment to ensuring minimal consumption of material goods, ensuring recycling of waste, and valuing the dignity in labour. This means, for example, that they do not shy away from menial work like cleaning the classroom or picking up garbage.

We have clubbed children in the age groups of 3, 4 & 5 years into one level, 6 & 7 years in a second level, 8 & 9 years in a third level, and 10 & 11 years in a fourth one. This helps peer learning among children of different age groups, and makes it easier for the teacher to have some support from the older kids. Since children are introduced to the study of 'subjects' only after they reach the age of 12 years, we have developed an integrated learning curriculum for children below this age. This curriculum is based on five elements — Sun, Water, Earth, Air and Space. We also write stories and songs to help children observe natural phenomena, question and deduce answers to their questions, and understand concepts related to each of these elements.

Rather than use a fixed pedagogical approach, our focus is on listening to the child, and engaging in intuitive explorations of the natural world. I think that this the only way to be with a child. The essence of this kind of engagement is that the child leads and the adult follows. Any guidance that the adult offers is from personal wisdom, gained through their own life experience.

cooking or making soaps and organic colours (from flowers, plants, and seeds) offer the opportunity to explore many interesting chemical transformations. This includes the transformation of batter into a cake in an oven, the puffing up of a *puri* or *chappathi* in hot oil due to exposure to heat, or transformations in the taste of food when different ingredients are added. Similarly, the whole world of dyes opens up to children once they understand how colour is made from plants.

Learning through inquiry

We also perform many small experiments every day, going through the stages of hypothesis, experimentation, observation, and inference. For example, one such experiment emerged from a discussion about the role of sunlight in plant growth with children in the first and second levels. Two groups emerged — one believed that plants needed the sun, and the other didn't. To help them test their beliefs, we asked both groups of children to bring two things from home — plastic wrappers used for packaging (of biscuits or snacks), and some seeds (like ragi, wheat, green gram, *methi*, mustard, *jeera* etc. that are normally available in their kitchen). The plastic wrappers were cut and fashioned into bags that were filled with a mixture of equal parts of soil, sand, and compost. The seeds were put into these pot-like bags and watered. The children were asked to put their bags in places where they thought their plants were most likely to grow well. The children who believed that plants needed the sun, put their bags in a sunny place. In contrast, those who felt that plants could grow in the absence of sunlight, kept their bags in their classroom, under a shelf, in shaded dark places. Some kids were indecisive and did what their friends did. Both groups watered their plants and observed their growth. After a week's observation, the children who had placed their bags away from sunlight began moving them to sunny places. By our next discussion, all the children were convinced that plants needed sunshine, without having to mug it up as a fact from their textbook. This is when we introduced the concept of photosynthesis to explain that plants

Fig. 1. Children at Puvidham use simple tools in the garden. This gives them an opportunity to understand the mechanics of these tools in practical ways.

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also need minerals (which they absorb from the soil) and carbon dioxide (which they absorb from the air) to make food and grow.

Observing the growth of seeds into plants led to other observations and questions (see **Fig. 2**). Some of the children had noticed that some seedlings looked like a blade of grass, while others had come out with two thick leaves. At this point, we introduced them to concepts like monocotyledons and dicotyledons, and explained how this type of classification makes it easier to study the plants around us. We shared the fact that plants from these categories also differed in their root systems. Pulling a plant from each of these categories out of its pot by its roots, we introduced them to concepts like tap roots and fibrous roots. The children were then asked to observe these plants and draw all their parts, including their roots (see **Box 2**). This spurred the children to walk around school, trying to identify if the trees they saw were monocots or dicots.

Fig. 2. Children sowing seeds in the school garden.
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On their walk the next morning, one of the children wanted to know if their teacher would classify Palmyra trees under monocots or dicots. The teacher was stumped, and asked the child for time to find out. When, after some research, the teacher shared the correct answer with the child, she was again stumped by his exclamation: *"I already know it is a monocot"!* To her question, *"How did you find out?"*, the child responded, *"Because it's roots grow like that of a grass".* It is through this process of learning (the observation of events or properties, and deducing unknown facts) that children are introduced to the process of science.

Box 2. Art and Science:

Art is a vital part of the process of development of scientific thinking. The art of drawing offers a powerful way of understanding the visual world. Engaging in the process of drawing not only ensures the need to observe more closely, it increases a child's perseverance and patience. It can lead to immense improvements in their understanding of mechanics and structures. Also, since a drawing is both an expression of understanding and a visualization of possibilities, it enhances a child's concentration, imagination, creativity, and aesthetics. When we draw, our heart is silent and our mind is focused. We look through our eyes, understand the object with our brain, observe from the heart, and draw with our hands. In this action, our head, heart and hand work in coordination with each other.

The earliest drawings that children create are scribbles. We can learn a lot about a child's ability, interest, and imagination by talking to them about their scribbles. I have been repeatedly amazed by how much children can observe and learn without being taught. For example, a three-year-old scribbled a patch of lines. I asked her what she had drawn. She said it was a cow. It is likely that this was just a random response. I said, *"Wow! That is a beautiful cow. But I can't see its horns. Did you draw them?"* She replied: *"No, I didn't draw".* She then proceeded to draw horn-like scribbles. When I asked her where the tail was, I was amazed to note that she drew one at the other end of the scribble. I asked about the cow's legs, and she drew four legs in spite of not knowing numbers. And she drew them in the middle of the scribble. It seemed obvious that the child had a sense of what is where, and can make a correlation of quantity too! Isn't this scientific thinking? Doesn't it involve scientific thought, and improve scientific temper?

One of the problems with connecting art with science is that art is often judged solely for its beauty. This is why many older children, and even teachers, may be reluctant to draw. They have formed the opinion that they cannot draw. Not drawing impedes their ability to learn through observation. When art is used to learn science, the ability to observe and draw key features is much more important than the beauty of the drawing. Not only children, but teachers too need to be encouraged to engage in drawing. Only then will they be able to appreciate the power of drawing in learning.

Box 3. The teacher as a facilitator:

The most important aspect of this kind of learning environment is that the teacher acts as a facilitator. When a child asks a question, the facilitator engages with the question in a way that helps further the logical thinking and deductive abilities of the child.

Here is an example:

Child: *"How does the water go to the sky and become rain?"*

I: *"Wow! What a wonderful question? How come I never thought about it? I too would like to know how the water got there. How do **you** think it got there?"*

Child: *"It must have been there already."*

I: *"Hmm! That is possible! Actually, I have always wondered where the water in my washed clothes went. It must be going into the air."*

This is how I slowly led her to the concept of evaporation. We then did an experiment on condensation that allowed her to frame a response to her question without having to be told about it.

When the teacher shares answers to all their questions, children become dependent on the teacher and believe more in the teacher than in themselves. It is instead important for a teacher to nurture the humility required to surrender to the child's questions. The teacher is not there to show the child how much they know, but to help the child to discover answers for themselves.

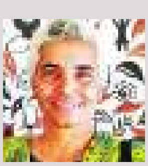
Parting thoughts

Our focus at Puvidham is on nurturing people who care about the earth. People who will live more responsibly, raise their voice for, and take action to protect and maintain life on our planet. Towards this goal, we don't teach science; we try to make space for the development of the natural curiosity of the child (see **Box 3**). Children learn science naturally through the process of observation, deduction, expression, and correction. We don't just teach science as an intellectual exercise; we try to get children to care. Children become acutely aware of their surroundings, and their contribution to the havoc on the planet. We don't just view science; we try to ensure that children know that science cannot be segregated from everyday life. That life is an integration of experiences. And that each experience is an opportunity to learn to engage with life in a wiser way, and for the wellbeing of all living creatures.

Key takeaways

- Involving children and adults with the many activities of everyday life in and around school offers many opportunities to observe, question, and investigate natural phenomena.
- Encouraging inquiry and experimentation in the process of learning – observation of events, processes, or properties and deducing unknown facts – offers students a practical introduction to the process of science.
- Encouraging children and adults to use art to record their observations can improve their scientific thinking as well as their understanding of mechanics and structures.
- When a teacher helps a child find their own answers to questions, they help further the logical thinking and deductive abilities of the child.

Note: Source of the image used in the background of the article title: Experimenting. Credits: Meenakshi Umesh. License: CC-BY-NC.



Meenakshi Umesh was born and brought up in Mumbai. She has always had a lot of questions about the disparities in human societies. By the age of 18, she had reached the conclusion that these disparities were perpetuated through mainstream education. This led her to purchase some land in Dharmapuri in 1992, and start the Puvidham Learning Centre in 2000. Her aim is to contribute to the creation of an anarchic and egalitarian society of people who recognise nature as their only god, and our planet as their only home.

FUN WITH ARCHIMEDES' PRINCIPLE

MANISH YADAV

This article presents the journey of a group of science teachers who explore Archimedes' principle, and related concepts, through well-loved fables like that of the Thirsty Crow, as well as a series of simple, open-ended experiments with readily available materials.

Although most teachers agree on the need for experiments in the teaching and learning of physics, experimentation in schools often consists of students being asked to follow a series of instructions so as to arrive at a predetermined result or verify a previously stated law. This approach is aimed more at getting predictable results rather than encouraging students to use experiments to explore questions. This is perhaps one of the reasons why teachers see very little value in conducting experiments in their classrooms. How do we rethink the kind of experiments we use to teach physics in school?

We explore this question by using an experiment-based approach to understand Archimedes' principle. Each of these experiments may be demonstrated by the teacher, or performed by students as group activities. Ask students to predict what they expect to see before the experiment is performed. Draw them into discussion to help them recognise the prior experiences and assumptions that form the basis of their predictions. Once their predictions have been tested through experimentation, ask students to reflect upon and discuss their observations with each other. This approach will allow students to **arrive** at an understanding of the principle, on their own, through deeper inquiry.

Can the thirsty crow story be true?

Many of us have heard of the story of the thirsty crow that used pebbles to get to the water in a clay pot. But how many of us have attempted to verify this story? We designed this experiment to help begin an exploration of Archimedes' principle (see **Activity Sheet I**). Start by reading out the story. Then encourage your students to experiment with a variety of materials to bring water to the brim of a pot. This will get them to think more deeply about the floating and sinking properties of objects in water.

Factors that cause sinking or floating

We designed this experiment to help students think more deeply about the floating and sinking properties of objects, and their relationship with properties of the liquids into which they are dropped (see **Activity Sheet II**). For simplicity, you can even start this experiment with one liquid – water. Ask students a variety of questions to get them to identify factors that influence floatation. Students at the school level will most likely answer these questions by mentioning concepts like mass, volume, density, area, etc. You may also get responses like colour or length. Selecting objects that vary widely in colour and length can be used to demonstrate that these properties have no connection with floatation (see **Box 1**).

Box 1. What kind of objects can we use for this experiment?

There is no rule about the set of objects chosen for this experiment. They've been chosen because they display different conditions of floatation in different liquids. Teachers can choose to have an entirely different set of objects that fulfil this same broad condition.

The volume of objects and the liquid they displace

We designed this experiment to explore the relationship between the volume of objects and that of the liquid they displace (see **Activity Sheet III**). To do this, we test the floatation of cuboids and spheres made of wood, metal, and glass in water. Start this experiment by asking students to calculate the volume of the cuboids and spheres by making necessary measurements and using appropriate mathematical formulae. Once they finish doing this, ask students to drop these objects one-by-one into the water in the measuring jar. By marking the level of water in the measuring jar before and after each of the objects are dropped into it, students can calculate the volume of water displaced in each case. Encourage your students to compare these values with the volumes calculated at the beginning of this experiment. Can they identify any broad patterns?

These are some observations that are typical of this experiment:

- The volume of an object that sinks is equal to the volume of the liquid it displaces.
- The volume of an object that floats is greater than the volume of the liquid it displaces.

These observations can be expressed mathematically:

V_{object} = V liquid displaced when object sinks.

V_{object} > V liquid displaced when object floats.

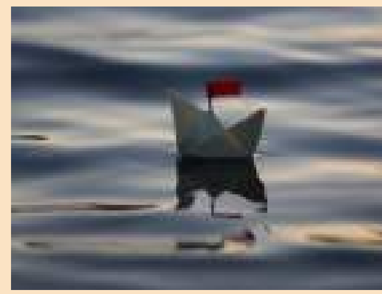
Mass and density in floatation and sinking

We designed this experiment to explore the relationship between the mass and volume of objects and that of the liquids they displace with their floatation (see **Activity Sheet IV**).

This activity has two stages. In the first stage, ask students to measure the mass of cuboids made of wood, iron or soap, and calculate their volume and density. Then ask them to dip the cuboids one-by-one in water, and record the mass and volume of displaced water in each case. Given the fact that objects of the same volume can show different floatation properties (one floats while the other may sink), encourage students to use these observations to explore the relationship between the mass, volume, and density of an object with its tendency to sink or float. You can also ask them to test this relationship with objects of irregular shape (see **Box 2**). This will help them arrive at a relationship like this:

Box 2. Does the shape of an object have any role to play in its tendency to sink or float?

Give students some clay or aluminum foil and a tub of water. Encourage them to use the clay or foil to carve out differently shaped objects of the same mass, drop them in water and record the volume, mass, and density of water they displace. Since differently shaped objects have different contact areas, they may displace different volumes of water.



Does the shape of a boat help it float? What makes it sink?

Credits: Tim Green URL: https://www.piqsels.com/en/public-domain-photo-sgymf. License: CC-BY.

This can lead to a discussion about how the shape of boats and ships are designed for floating despite being made of material that has a much higher density than seawater.

	Volume Relation	Mass Relation	Density Relation (Mass / Volume)
Sink	Vo = Vw	Mo > Mw	Do > Dw
Float	Vo > Vw	Mo = Mw	Do < Dw

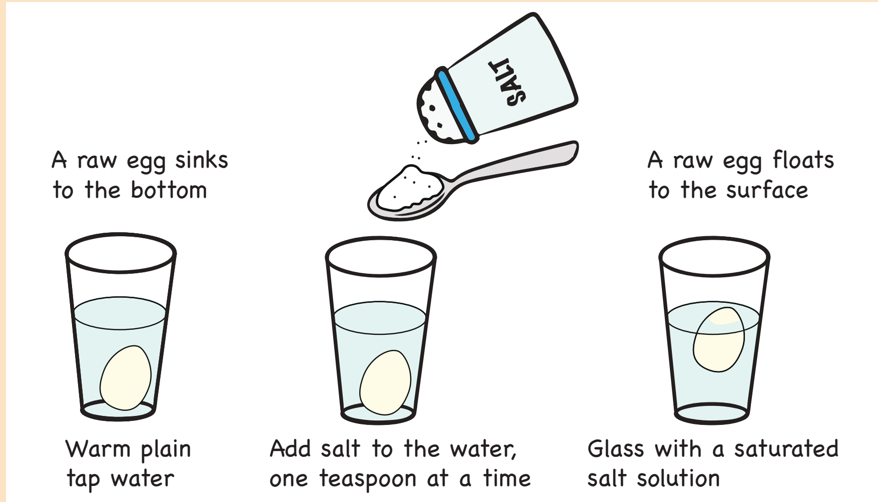
Here,

- Vo stands for the volume of the object.
- Vw for the volume of water displaced by it.
- Mo stands for the mass of the object.
- Mw stands for the mass of the water displaced by it.
- Do stands for the density of the object.
- Dw stands for the density of the water displaced by it.

Box 3. Will an object's tendency to float or sink change if it is dropped in a liquid with the same density?

We know that objects float on the surface of liquids of higher density, or below the surface of liquids of equal density. We also know that objects sink in liquids with a density lower than their own.

You can help students arrive at this understanding with an egg, some tap water, and some table salt. Ask students to predict if the egg would float or sink if dropped into water. Once they have made their predictions, drop the egg into the water, and allow students to watch it sink. Then, start adding salt to the water, gradually adding enough to cause the egg to start floating. Ask students what they think the salt does to the water to cause the egg to float.



Why does salt make an egg float in water?

Adapted from: R. Bishop, How Salt Behaves, WORLDkids. URL: https://kids.wng.org/node/1942.

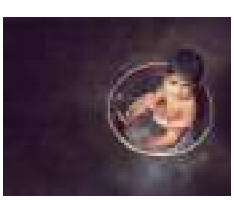
You can also explore this question by dropping a piece of carrot first in some tap water, and then in a saturated sugar or citric acid solution at room temperature.

In the second stage, you can extend this exploration to other liquids, like alcohol, citric acid, salt solution, and sugar solution (see **Box 3**). Ask students to think of factors that cause an object to float (partially or fully) in one liquid and sink in another. This will help establish the fact that floating and sinking do NOT depend upon object properties alone.

Conclusion

These are just some ideas for experiments that can be used to explore a concept in physics in more engaging ways. This kind of approach provides students with the opportunity to **explore** and **discover** these concepts for themselves. Through such experiences, they begin to construct their own knowledge. Wouldn't you want to try these experiments out too?

Key takeaways



- Students can develop a strong understanding of Archimedes' principle through a series of simple, enjoyable, and open-ended experiments with readily available materials.
- An experiment-based approach that encourages students to predict, test, reflect, and discuss observations can help them 'arrive' at an understanding of core concepts and principles, on their own, through deeper inquiry.

Acknowledgements: I would like to thank my colleagues Rakesh Tewary and Ganesh Jeeva (co-developer of the module 'Let's do physics'). I would also like to thank Azim Premji Foundation Jaipur state and Tonk teams for their help in organising the training workshop 'Let's do Physics' with 35 Government teachers at Nawai, Rajasthan in December 2012.

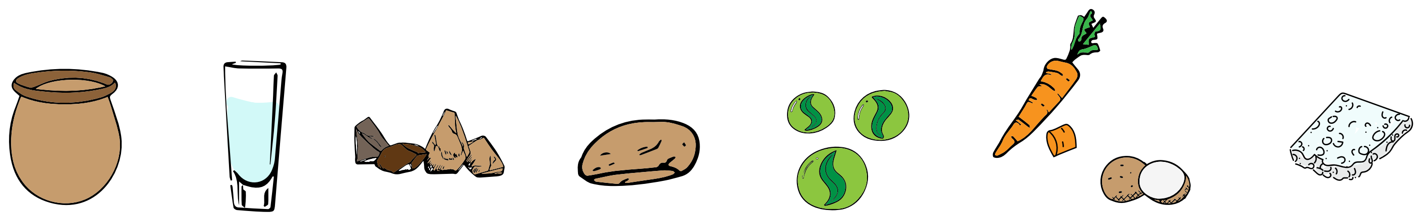
Note: Source of the image used in the background of the article title: https://pixahive.com/photo/a-toddler-bathing-in-a-tub/. Credits: Petrichor, Pixahive. License: CC0.

ACTIVITY I : THE THIRSTY CROW STORY

Have you heard this story before?

It was a hot summer day. A thirsty crow was searching for water. After much searching, it found an earthen pot with some water in it. The crow tried to push its head into the pot, but couldn't reach the water in it. It then tried to tilt the pot so that some water would flow out, but the pot was too heavy for it. Looking around, the crow spotted many small pebbles. It used its beak to drop these pebbles, one by one, into the pot. The water level rose till the crow could reach it with its beak. The crow drank its fill, and flew away.

You will need:



An earthen pot, some water, some small and big pebbles, one big stone, some differently sized marbles, some differently sized vegetable pieces, some pieces of thermocol.

Think about & discuss:

- Do you think it's possible to get to water in a pot like this? Why?
- In your opinion, what is the least amount of water a pot would have to contain for a crow to reach it by dropping pebbles into it? How would you check this?
- How many small pebbles would you need to reach the water? Instead of dropping many small pebbles, what if we were to gently drop one big stone into the pot? What do you think would happen?
- What else (marbles, vegetable pieces, thermocol, etc.) could be dropped into the pot to raise the water-level in it?
- Would it be correct to say that the water level rises to the brim only if the pot is filled with enough water to start with? Is this water level half or two-thirds of the volume of the pot?

Contributed by:
Manish Yadav, who works in the fields of science and mathematics education with the Azim Premji Foundation. He has conducted many programmes in science education for teachers and teacher educators.

ACTIVITY II: FACTORS THAT AFFECT FLOATATION

Aim:

To identify factors that influence the floating or sinking of an object in a liquid.

You will need:

- Liquids: three glass tumblers (each with a volume of 250 ml) — one filled with water, a second with a sugar/salt solution, and a third with alcohol.
- Objects: A piece of cork, an eraser, turmeric, betel nut, a metal paperclip, a piece of candle, a cut-pencil piece, some clay, some differently sized pieces of carrot and potato, and a ball of crumpled aluminum foil.

What to do:

- Imagine that you drop each of the objects one-by-one in each of the three solutions. Do you think they will sink or float?
- Now, actually drop each of these objects in each of these solutions. Observe if they sink or float.
- Record your predictions & observations in the table.

Think about:

1. Which of your predictions were different from your observations? How would you explain the difference?

2. What kinds of objects tend to float? Is there anything common between them that causes them to float?

3. What kinds of objects tend to sink? Is there anything common between them that causes them to sink?

4. A crushed aluminum foil floats in water. Could you think of a way to make it sink?

5. Did you find any objects that sink in all three liquids? Can you think of a reason why an object that sinks in alcohol, sinks in water and a sugar/salt solution too?

6. Did you find any objects that float in all three liquids? Why do you think these objects float in all three liquids?

7. Did you find any solutions in which all these objects sink? Can you think of a reason why a solution that causes a metal pin to sink causes a cork to sink too?

8. Did you find any solutions in which all these objects float? Why do you think all objects float in this solution?

Discuss with others:

- What properties of an object make it sink or float?

- What properties of a solution make an object sink or float in it?

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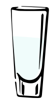
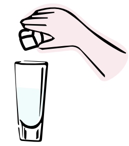
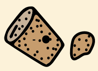
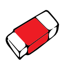
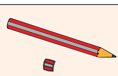
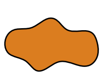
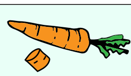
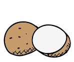
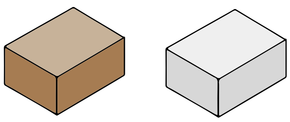
OBJECTS	SOLUTIONS					
	 Water		 Sugar/salt solution		 Alcohol	
	Predicted	Observed	Predicted	Observed	Predicted	Observed
 Piece of cork						
 Eraser						
 Turmeric						
 Betel nut						
 Metal paperclip						
 Piece of candle						
 Cut pencil piece						
 Clay						
 A piece of carrot						
 A piece of potato						
 Ball of crumpled aluminum foil						

ACTIVITY III: OBJECTS & SOLUTIONS

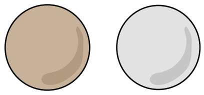
Aim:

To explore the relationship between the volume of objects and the volume of the liquid they displace.

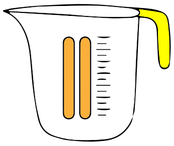
You will need:



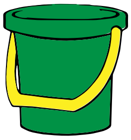
2 cuboids (one made of iron and the other of wood)



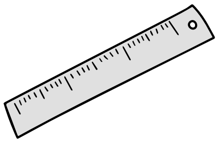
2 spheres (one made of wood, the other of glass)



A measuring jar



A bucket of water



A half-foot scale/ measuring tape to measure the dimensions of the cuboids/spheres

What to do:

- Calculate the volume of the cuboids and spheres.
- Drop each of these objects in a measuring jar filled with water. Observe any change in volume of the water inside the jar.
- Record your observations in the table below.

Objects	Measured volume	Does the object sink or float in water?	What volume of water does the object displace?

Think about:

1. Which objects displace a volume of water that equals their own volume? Do you think this has anything to do with the properties of the object?
2. In which cases is the volume of the object different from the volume of the water it displaces? Do you think this has anything to do with the properties of the object?
3. Does the volume of displaced water ever exceed the volume of the object dropped into it? Why do you think this happens?

i wonder... Rediscovering school science

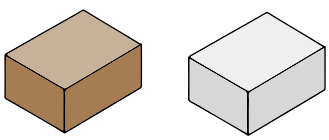
Contributed by:
Manish Yadav, who works in the fields of science and mathematics education with the Azim Premji Foundation. He has conducted many programmes in science education for teachers and teacher educators.

Azim Premji University

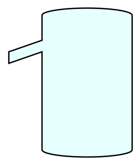
ACTIVITY IV: HOW AN OBJECT'S MASS, VOLUME & DENSITY AFFECT ITS FLOATATION

Aim:
To explore the relationship between the mass, volume, and density of objects with their tendency to sink or float.

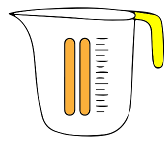
You will need:



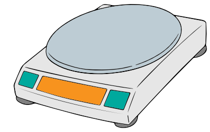
One cuboid block of wood and another of iron of the same dimensions (identical except for the material)



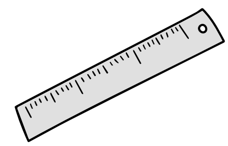
An overflow jar



A measuring jar



An electronic balance to measure mass of the displaced liquid (with an accuracy in grams)



A half-foot scale to measure the dimensions of the cuboids

What to do:

- Find the volume, mass and density of each of the cuboids:
  - o Use the electronic balance to weigh each of the cuboids. The reading that appears on the balance will be of its mass (= w/g, where w = weight & g = acceleration due to gravity = 9.8 m/s^2 on earth).
  - o Calculate the volume of the cuboids using the scale to make necessary measurements.
  - o Calculate the density of the cuboids using the formula: density = mass/volume.
- Use the electronic balance to weigh the empty measuring cylinder. Then, fill the overflow jar with water. Place the measuring cylinder below the spout of the overflow jar. Dip the wooden cuboid into the water in the overflow jar. Record the volume of water that is displaced from the overflow jar into the measuring cylinder. Now, weigh the measuring cylinder with the displaced water (subtracting the mass of the empty cylinder from this value will tell you the mass of the displaced water).
- Repeat this process with the iron cuboid.
- Record your measurements & observations in the table on the next page.

Think about:

1. Which of the two cuboids floats in water, and which one sinks? Since both cuboids have the same volume, how is the sinking or floating of an object related to its mass and density?

2. Which of these three properties of an object — its mass, volume, or density — can you correctly calculate using the water displaced by it?

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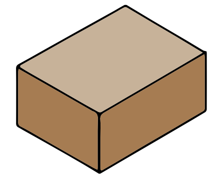
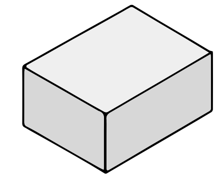
		 Wood cuboid	 Iron cuboid
Does the object sink or float?			
Mass	Of object		
	Of water displaced by object		
Volume	Of object		
	Of water displaced by object		
Density	Of object		
	Of water displaced by object		

References:

1. Physics in the Elementary School, Harry O. Gillet, The Elementary School Teacher, Vol. 4, No. 10 (Jun., 1904), pp. 688-692.
2. Generative Role of Experiments in Physics and in Teaching Physics: A Suggestion for Epistemological Reconstruction. Koponen, I.T., Mäntylä, T. Sci Educ 15, 31–54 (2006). URL: https://doi.org/10.1007/s11191-005-3199-6.
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EVOLUTION OF LAUGHTER

We begin to laugh from a very young age, and for a variety of reasons. But did you know that we are not the only living beings on earth who laugh? The great apes (like gorillas, orangutans, chimpanzees, and bonobos) laugh too, although their laughter can sound very different from ours (the laughter of a chimpanzee sounds like panting!).

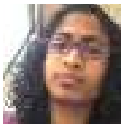
Laughter may have emerged as a social phenomenon. For example, laughter in the great apes is mostly seen in the young who use it in play, or when they are tickled. This signals their happiness to their playmates and encourages social bonding. Humans laugh in every possible kind of social interaction. In fact, it's been observed that people are 30 times more likely to laugh in a group than alone. You may have noticed that just the sound of laughter can make us smile (or laugh); knowing the context is not necessary.

Scientists believe that we may have inherited this adaptive trait from an ancestor that is common to humans and great apes, and lived at least 10-16 million years ago. This has led us to ask — does this trait offer any survival advantages? We now know that laughter triggers the release of endorphins. These are a group of hormones in the brain that help in pain tolerance and induce a sensation of pleasure. Laughter can also help reduce anxiety, strengthen our immunity, and increase our longevity. This is especially true when laughter is shared with a group of people. When people laugh in a group, their shared pleasure also helps create, reinforce, and maintain social bonds.

In fact, scientists believe that the prosocial effect of laughter may have helped early human societies expand more than any other primate society on earth. How? Nonhuman primates use one-on-one interactions (like grooming) in order to bond and form intimate social groups. Since establishing bonds through such interactions takes time, the intimate groups and the larger communities they are part of are automatically small in size. In humans, laughter may have been one of the earliest traits to help many people interact with each other at the same time, without physical contact. These social bonds may have helped create intimate social groups and communities that were much larger than those of nonhuman primates. Later advancements like religion and culture may have helped human societies grow even larger.

Since its emergence, laughter has evolved from a simple playful expression to the variety of meanings it carries today in our society. We might not have fully grasped the importance of laughter in human evolution, but it remains a very essential aspect of our social lives and our well-being. So meet up with your friends (online), and have a good laugh!

Credit: Sourced from Pickpik (royalty-free image). URL: https://www.pickpik.com/school-children-happy-smile-joy-smiling-75188. License: CC0.



Vijeta Raghuram is the Program Manager, Education at IndiaBioscience, Bangalore. Fascinated by nature's mysteries, she believes that the popularization of science is her true calling. She can be reached at vijeta@indiabioscience.org.

OBSERVING THE MICROBIAL WORLD: STUDENT EXPERIENCES

MEENA KHARATMAL

Students carry many preconceived notions about microorganisms. Exploring puddles of rainwater provide an opportunity to reveal these notions and help students appreciate the diverse microscopic life-forms present around them. Can teachers use such explorations to offer students a first-hand experience of the process of science, and help develop their scientific skills?

Have you ever observed water in the pits and puddles that appear after the rains? Each of these temporary collections of rainwater act as micro-ecosystems, supporting many different tiny life-forms that vary from place to place and season to season. Such observations of the natural world are not only vital to the practice of science, but also to its teaching and learning in the classroom. In fact, an interest in science often begins with observations of our immediate surroundings that engage our curiosity.

To encourage students to study such micro-ecosystems in and around their schools, we designed a learning unit comprising a series of simple, hands-on activities and shared it with teachers from various schools (see **Box 1**). This article was derived from the classroom experiences shared by of one of the teachers with 20 students of Grade VIII.

Students' preconceptions about microorganisms

To explore students' prior knowledge about microscopic life-forms, their prevalence in our surroundings, and concepts like 'life' and 'dormancy', they were asked to observe as many puddles as they could find in and around the school. To gain insight into their ideas about microbes, the students were then asked to respond to the following questions:

(a) The existence of microorganisms

All the students showed an awareness of microscopic life forms by responding in the affirmative to the question **'Do you think there is life in those puddles?'**. Some offered reasons: *"...because they (puddles) can provide all necessary living elements to the microorganisms"*. Interestingly, some students expressed the belief that millions of microorganisms could exist in puddles as small as 10 cm in diameter (see **Fig. 1a, 1b** & **1c**).

Box 1. Examples of links to curriculum:

A review of the Grade VIII NCERT textbook showed at least two chapters (2 and 8) that are directly linked to the aims, concepts and activities that we explore in this learning unit.

- **Chapter 2:** 'Microorganisms: Friend and Foe' includes two activities (2.1 and 2.2) that are intended to enable a hands-on approach to observing microorganisms from soil samples or pond water. This learning unit was developed by extending these activities to help middle school students develop the observational, recording, drawing, describing, and measuring skills required to learn science.
- **Chapter 8:** 'Cell Structure and Function' has an extended learning section about the use of microscopes. This learning unit provides a direct opportunity to observe microorganisms under a microscope.

(b) Sources of microorganisms

When asked **'Will there be life forms in a dry sample (for e.g., dry soil)? If yes, where do they come from — soil, water, or air?'**, most students expressed the belief that even dry soil could contain microorganisms. Many of them justified this by sharing that microorganisms were known to survive *"in any type of climatic conditions, from marshy lands to dry deserts"*. Most students believed that air was the primary source of microorganisms (see **Fig. 1d**). For example, many of them expressed beliefs like: *"if soil is dry there will be no water in it, only air can be there"*, implying that any microorganisms in a dry soil sample would come from the air. Some students mentioned that soil and water could also act as sources of microorganisms (see **Fig. 1e**). Interestingly, many students who believed that air was a source of microorganisms did not believe that water could be a source too.

(c) Survival/dormancy

Responses to the question **'When the puddle or a wet soil sample dries up, what do you think happens to the life forms living in it?'**, revealed conflicts and confusion in students' understanding of the factors necessary for the survival of microorganisms. Many students believed that water was essential for the survival of microorganisms, and its absence would kill them (see **Fig. 1f** & **1g**). This was reflected in responses like: *"If there is no water then the microorganisms will die"*, or *"When the soil sample dries the microorganisms will die"*. Other students believed that different microorganisms would respond to the lack of water in different ways. For example, some believed that: *"When the soil sample dries... the number of microorganisms will decrease in number"*. A few others suggested that: *"When the wet soil sample dries up... some microorganisms will [be] left over as we know that microorganisms can live in every climate"*. These responses reflected some understanding about the dormancy condition (see **Box 2**). One student expressed the belief that the survival of microorganisms in dry soil would depend on their tolerance to drying due to heat (from the sun): *"When the wet soil sample dries, the life forms such as bacteria can exist there. But some microorganisms can't resist the temperature"*. Another student expressed the surprising belief that *"When the wet soil samples dries the organisms that require water may die but the other organism may live in it"*. This student seemed to believe that some microscopic life forms did not require water to survive.

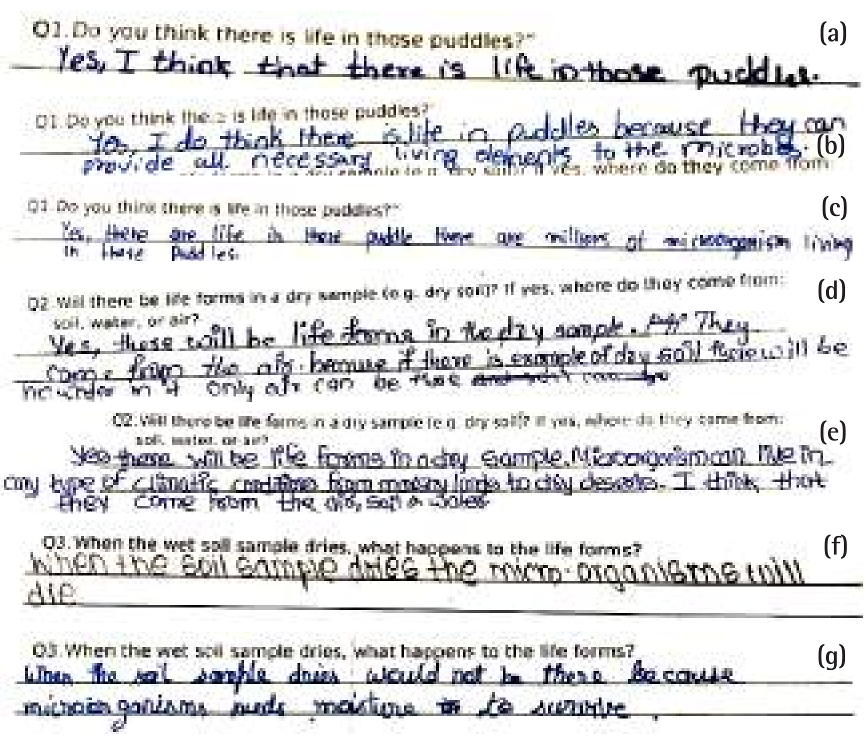


Fig. 1. **Student responses based on their preconceptions about microorganisms.**

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Box 2. Dormancy in microorganisms:

Microorganisms have a higher degree of physiological tolerance and can undergo a reversible state of low metabolic activity. This ability, known as **dormancy**, helps them overcome unfavorable environmental conditions. Dormancy not only protects microorganisms from death and possible extinction, it also plays a role in ecosystem stability and biodiversity.

Many students seemed to associate the presence or absence of water as the only criteria essential for the survival of microorganisms. While students in this grade are usually aware of hibernation in reptiles and mammals, they have not yet developed an understanding that microorganisms can be alive even in dormancy condition. This may be because science textbooks do not engage with the dormancy of microorganisms at the conceptual level. Even if they did, students may find it difficult to relate the concept to life at a microscopic level. This simple exercise can help students understand the dormancy condition in microorganisms, and connect it to hibernation and aestivation in larger animals. It can also help establish links between microorganisms and concepts like the environment, ecosystem, diversity, survival, and evolution.

(d) Microorganisms in our surroundings

When asked **'Will there be life forms in a drop of clear water? Why do you think so?'**, many students stated that this was possible, *"because the clear water provides all the necessary elements of the microorganisms"*. Some students suggested that microorganisms could multiply rapidly in water, and would therefore be quite numerous. Others expressed the belief that the microorganisms or bacteria in clear water would be beneficial to us. Some students were less certain, and wondered about ways of confirming this possibility. This was evident in responses like: *"microorganisms cannot be seen with naked eye. Then how we can see that there are life forms in drop of water or not"*. Or, *"I don't think so because if the water is clarified and it is clear microorganisms are also removed but some microorganisms may be living in that drop of water because we cannot see them"*.

Encouraging microscopic observations of microorganisms

To put their ideas to test, students were asked to observe soil and water samples under a microscope, and use notes and drawings to record details of any life forms they spotted (see **Box 3**).

Students observed and described the samples under two magnifications (10X and 45X) of the microscope (see **Box 4**). Their meticulous records of these observations describe the colour, shape, size, and location of microorganisms in the visual field. For example, responses regarding colour mention blue-, black-, purple-, and violet-coloured microorganisms. Similarly, those regarding shape mention irregular, thread-like, elliptical, and circular forms of microorganisms (see **Fig. 2a, 2b & 2c**).

In response to the question **'Do you think the objects you see under the microscope are living or non-living? How can you tell?'**, all the students expressed the belief that motile microorganisms were living, and immotile ones were dead (see **Fig. 2d, 2e & 2f**). Students were also encouraged to collect soil and water samples (like samples of drainage water, tap water, tank water, and

Box 3. Facilitating student observations under the microscope:

Teachers may need to start this task by:

- Familiarizing students with a compound microscope, its parts, and the function of each part. This can be coupled with the activity of observing slides.
- Helping students in preparing slides and observing them under the microscope. This may involve help with seeing through the eyepiece, focusing the objective lens, aligning the slide, adjusting the light, and calculating the total magnification at which the slides are observed, etc.

Box 4. Observe, describe, draw, and record microorganisms:

Guidance for students:

- Prepare a slide by placing a drop of the sample on the slide. You may cover it with a cover slip.
- Observe the slide under the microscope. Explore all the areas of the slide, and try to record as many different objects that you can see.
- Change the magnification, and try to see the same objects magnified. Carefully observe any living organisms in the visual field, and note their relative sizes.

Questions for student worksheet:

- What do you observe under the visual field of the microscope? Describe it in your own words in terms of their number, size, shape, color, motility, etc.
- Do you think the objects that you see are living or non-living? Why do you think so?
- Draw what you observe on a plain or graph paper (to be provided by the teacher). You can draw by first creating a circle of your visual field and using the inside of the circle for drawing almost all the microorganisms that you observe as per their position, size, shape, color, etc.
- Change the magnification of the microscope, and draw the same microorganisms at various magnifications on a plain or graph paper. You can follow the same method of drawing inside the circle of the visual field.
- Try to identify the life forms that are being observed. Use the **Field Guide** (to be provided by the teacher) to identify the life forms that are closest to what you have observed on the slide.
- Write down the names of the life forms that you find to be a close match with that of the key.

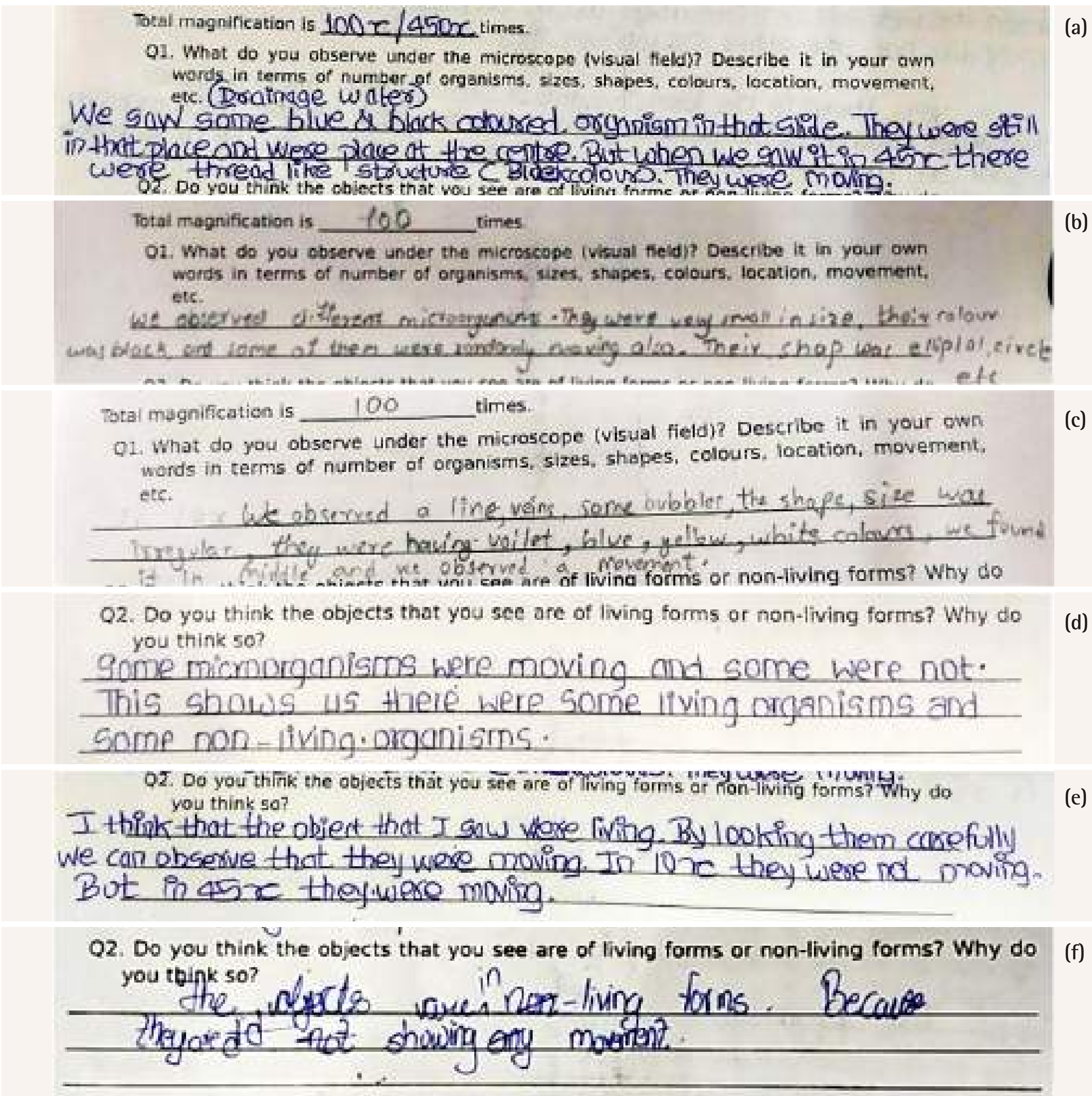
Suggestions for teachers: Once students have recorded their observations, they could be encouraged to look at each other's slides and compare notes, drawings etc. This could be followed by a class discussion on student observations, with particular emphasis on the kind of variety they can spot among life forms from different samples.

pond water) from different places in and around their school and homes (see **Box 5**). This activity offered students the opportunity to appreciate the diversity of microorganisms that inhabited their surroundings. It also made this study more exciting as students were able to relate the source of their samples with their observations under the microscope.

Box 5. Guidance for students in locating and collecting samples from their surroundings:

Locate some puddles filled with water at your doorstep, at home, or in school. If the location you choose is wet, collect a water sample with a spoon and place it in a container. If the location you choose is dry (i.e., if there is no puddle), then collect a soil sample with a spoon and place it in a container. Later, add a few drops of water, and leave undisturbed to allow the soil to settle down.

Label the collected samples with your name; the date, time and location of collection; and mention whether the sample is dry or wet.


(a)
Total magnification is 100x/450x times.
Q1. What do you observe under the microscope (visual field)? Describe it in your own words in terms of number of organisms, sizes, shapes, colours, location, movement, etc. (Drainage water)
We saw some blue & black coloured organism in that side. They were still in that place and were place at the centre. But when we saw it in 45x there were thread like structure (Black colour). They were moving.

(b)
Total magnification is 100 times.
Q1. What do you observe under the microscope (visual field)? Describe it in your own words in terms of number of organisms, sizes, shapes, colours, location, movement, etc.
we observed different microorganisms. They were very small in size, their colour was black and some of them were randomly moving also. Their shap was elliptical, circle etc

(c)
Total magnification is 100 times.
Q1. What do you observe under the microscope (visual field)? Describe it in your own words in terms of number of organisms, sizes, shapes, colours, location, movement, etc.
We observed a line, veins, some bubbles, the shape, size was irregular, they were having voilet, blue, yellow, white colours, we found it in middle and we observed a movement.

(d)
Q2. Do you think the objects that you see are of living forms or non-living forms? Why do you think so?
Some microorganisms were moving and some were not. This shows us there were some living organisms and some non-living organisms.

(e)
Q2. Do you think the objects that you see are of living forms or non-living forms? Why do you think so?
I think that the object that I saw were living. By looking them carefully we can observe that they were moving. In 10x they were not moving. But in 45x they were moving.

(f)
Q2. Do you think the objects that you see are of living forms or non-living forms? Why do you think so?
the objects are in non-living forms. Because they are not showing any movement.

Fig. 2. Students' descriptions of microorganisms from the soil sample as seen under a microscope.

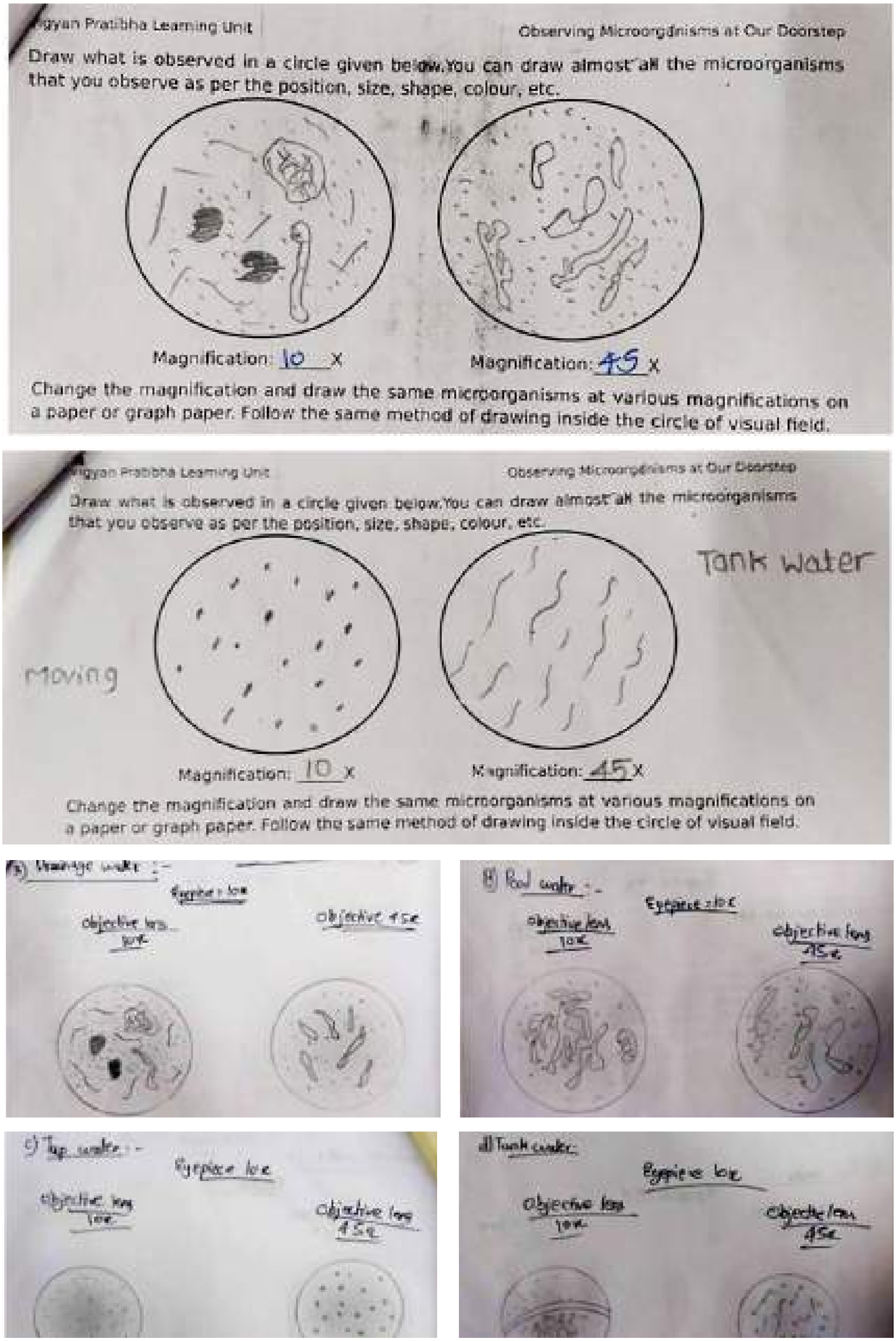


Fig. 3. Students' drawings. These reflect the microbial diversity seen in samples collected from a drain, pond, tap, and tank. Students' drawings of microorganisms as viewed under the two magnifications are also quite distinct from each other.

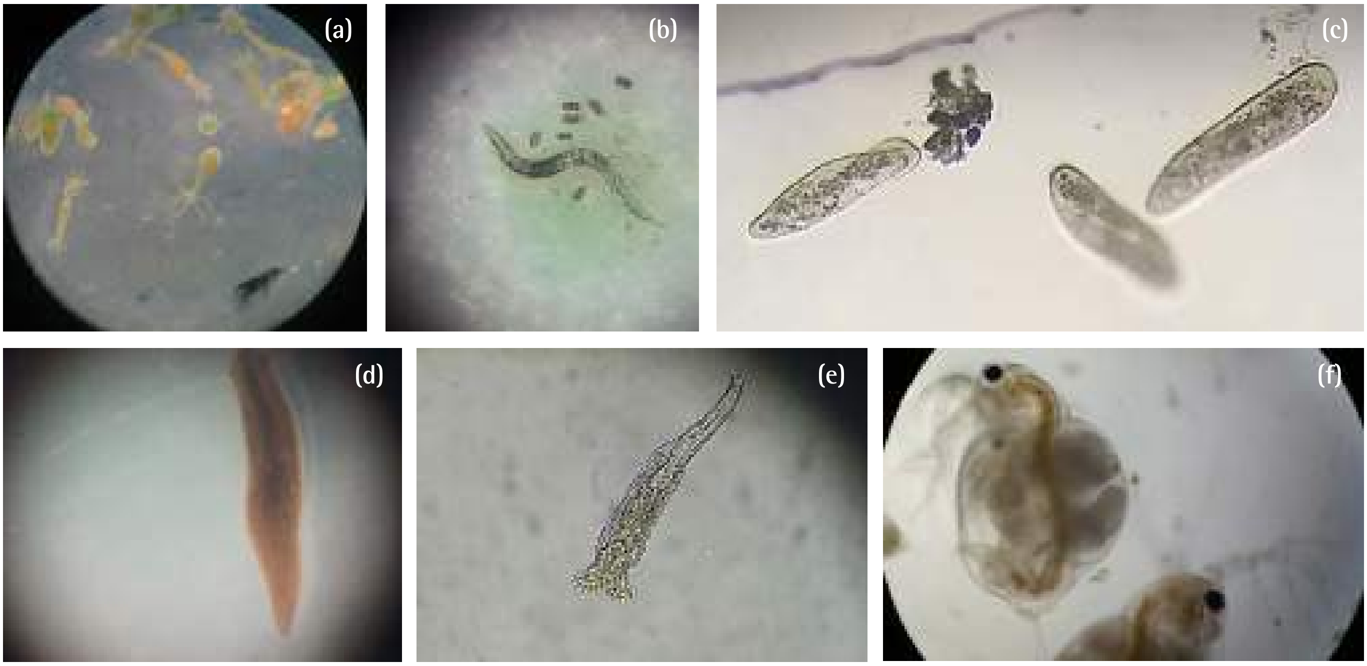


Fig. 4. Some of the life-forms observed in the soil sample: (a) Hydra **(b)** Nematode **(c)** Paramecium **(d)** Planaria **(e)** Rotifer **(f)** Water flea.

Students were asked to use drawings to record their observations of the samples (see **Fig. 3**). Encouraging students to draw what they have seen under the microscope rather than copying a diagram from a textbook can strengthen their powers of observation. Some students even managed to convey movement through their drawings. Finally, students were asked to try identifying some of the microorganisms in their samples by matching their own drawings with those in their textbook and in a key that we provided (see **Field Guide**). They were able to identify microorganisms like paramecia, rotifers, nematodes, and spirogyra more easily than others (see **Fig. 4**). Interestingly, these microorganisms are common examples in their textbook.

To help them appreciate how tiny microorganisms are, students were asked to measure the size or length of some of the life forms that they had observed in the visual field of the microscope. Many science labs use a micrometre slide to measure the size or length of objects under the microscope. For school labs that do not have a micrometre slide, we shared a simple method to measure size using a transparent ruler (see **Box 6**). Since students understand measurements of size in meters, centimetres, and millimetres, we encouraged them to use conversions of these units to estimate the size of microorganisms.

The students' worksheets on measurement showed that they found the estimation task difficult to understand and work out. One key challenge was related to the conversion of units, like millimetre to microns. Students also tended to divide the entire visual field size by the number of objects that they could see to get the size of each object. Since objects were not located at uniform distances in the visual field, this method offered an estimate of the size of visual field rather than the size of individual microorganisms. It is possible that students may need more attention and time to understand this calculation, its units of measurement, and method of conversion, etc.

Box 6. Measurement and estimation of microbial size:

Guidance for students:

Place a transparent ruler (mm divisions) under the objective lens (10X) of the microscope, and observe through the eye-piece. We can see two divisions of the ruler within the visual field. Since the two divisions of a scale are 1 mm apart, we know that the visual field is 1 mm (or 1000 microns) in diameter. We can use this measurement to estimate the relative size of the microorganisms that we observe under the microscope.

Questions for student worksheet:

Visual field = ... mm = ... microns

Size of microorganisms observed = ... microns.

Suggestions for teachers:

Teachers may need to calibrate the microscopes used for the study, and introduce students to the simple conversion of 1 mm = 1000 microns. They may also need to guide students in estimating sizes through this method.

Parting thoughts

This pedagogical learning unit is aimed towards drawing out prior beliefs of students regarding the existence, source, and dormancy of microorganisms. This will help students connect concepts related to microorganisms from the science curriculum with the diverse microorganisms found in their own surroundings.

It also offers them the opportunity to develop scientific skills like observing, hypothesising, drawing, and measuring. Often, students depend on the teacher to provide correct answers to all questions raised in the classroom. When this happens, most students tend to copy or replace their own response with that of the teacher's. The exercises in this unit have been designed to help students think, reason, and explain their observations in their own words. Hence, we request teachers to avoid offering clues or answers.

It is worthwhile to emphasize the importance of the drawing activity. Often, when asked to express their observations in words, students tend to use descriptions that are based on teacher inputs. On the other hand, student drawings reflect what they think they have actually observed. Drawing not only helps students develop their power of observation, it also encourages the habit of recording their observations.

Student records and collections of microorganisms from different microecosystems and in different seasons can be used to develop a school-level biodiversity mapping project. We request teachers to try this unit in their classroom and share their experience with us.

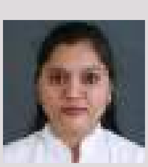
Key takeaways

- This learning unit provides an opportunity to identify students' preconceptions about the existence, source, and dormancy of microorganisms and discuss them in the classroom.
- It helps students connect concepts related to microorganisms from the science curriculum with the diverse microorganisms found in their own surroundings.
- It also offers students the opportunity to develop scientific skills like observing, hypothesising, drawing, and measuring.

Acknowledgements: The author acknowledges the support of the Department of Atomic Energy, Government of India, under Project Identification No. RTI4001. Acknowledgements are also due to Nagarjuna G., M. C. Arunan, Ankush Gupta, in developing the learning unit; and Mayuri Tawade and Sushma Rawool for conducting classroom observations. Also, happy to acknowledge the students and teachers of Atomic Energy Central School, Mumbai who used this learning unit.

Notes:

1. The activities in this article were developed as part of the CUBE (Collaboratively Understanding Biology Education) lab. CUBE is a program engaging students in project-based science experiments. More information about the CUBE program can be viewed at: https://www.gnowledge.org/projects/cube.html and https://metastudio.org.
2. The learning unit based on the activities were developed as part of the Vigyan Pratibha project. The objective of the project is to develop scientific skills with learning units related to school curricula. Currently the learning units are implemented by teachers in Kendriya Vidyalayas, Jawahar Navodaya Vidyalaya, Atomic Energy Central Schools. The entire learning unit with students' worksheet, and guidance for teacher's is available at: https://vigyanpratibha.in/index.php/microorganisms-at-our-doorstep/. Various other learning units for grades VIII & IX, and more information about the project can be viewed from: https://vigyanpratibha.in/.
3. Source of the image used in the background of the article title: https://pixabay.com/photos/trees-mirroring-puddle-rainwater-1932148/. Credits: Peggy_Marco, Pixabay. License: CC0.



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HIDDEN HOUSEMATES:
GETTING TO KNOW NATURE IN OUR HOMES

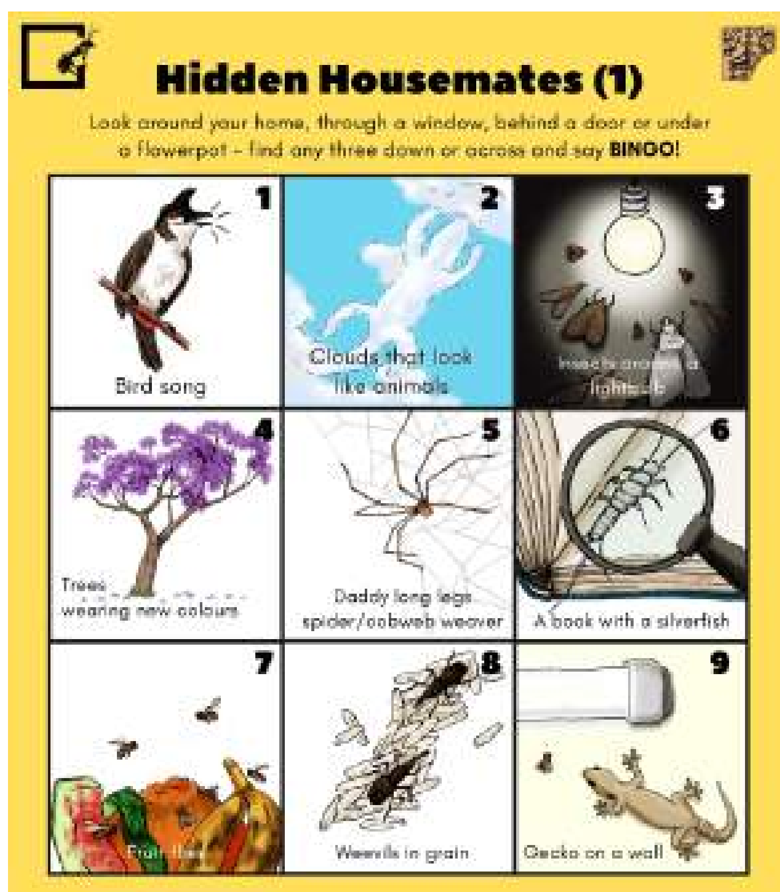
Is that little piece of paint from the wall moving? Who cleans up the crumbs from my kitchen while I'm asleep at night? Who lives in that little white tent in the corner of the wall?

Have you been asking yourself questions like these?

There is a lot of biodiversity that lives peacefully with us in our homes, balconies, gardens, and walls. The lockdown last year gave us the opportunity to spend time with them, and we discovered a new way to engage with nature.

But, first, what is 'nature'? Where can you find the natural world? Do you always need to go to faraway forests to experience the wonders of nature?

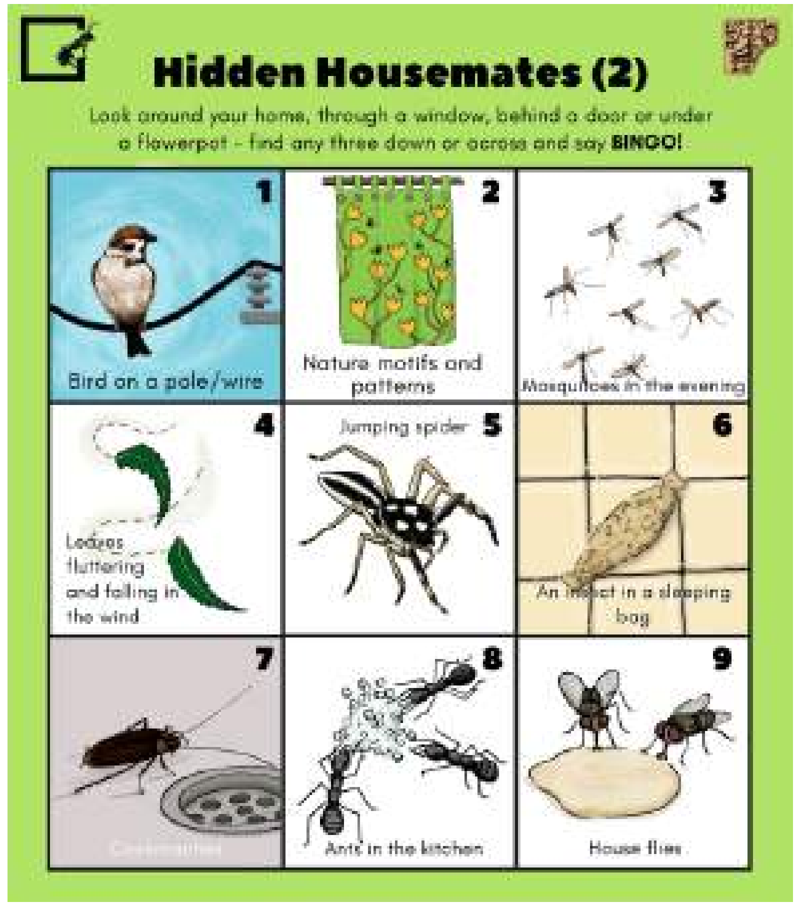
By looking under a table, behind a picture frame, following a persistent sound or even peering into a bag of grains, you can find a whole new habitat to explore! Discovering, observing, and documenting these 'hidden housemates' can be very exciting.

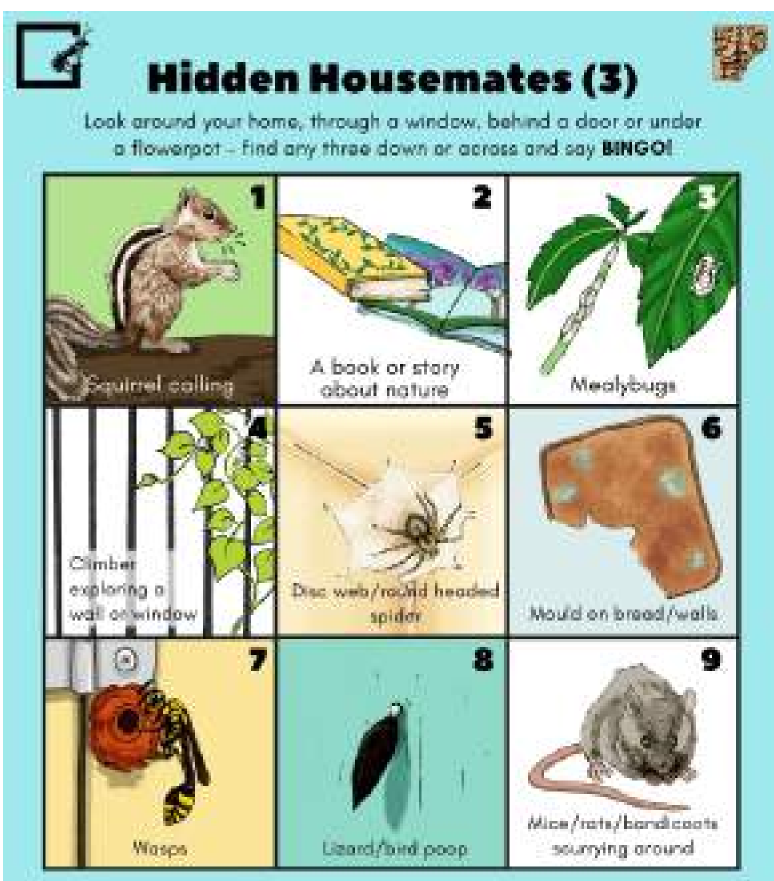


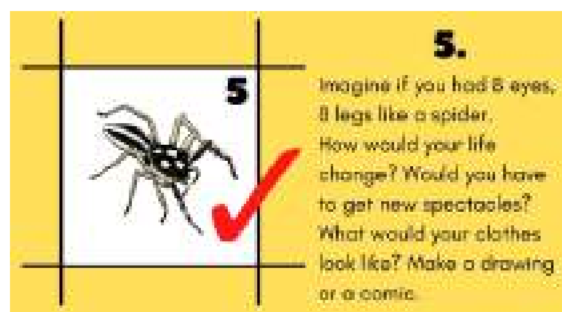
We have created a set of three Bingo sheets and activities that anyone can download, print, or even draw in their notebook to learn more about nature in and around their homes. These sheets can be found here: https://www.ncf-india.org/blog/hidden-housemates-part-1. Each sheet will introduce you to nine of these hidden housemates. You can go looking for them in your own space using the illustrated bingo sheet as your guide.

Once you find them, you may have more questions about who they are, or why they behave a certain way. You can discover more about each of them in their Bingo sheet, through a list of specially curated resources and activities for all ages. In addition to the English versions, modified editions of the activity sheets are also available in Kannada and Hindi.

Get ready to take a walk, look out of your window, or peer under a pot and get to know your hidden housemates!







Nature Classrooms works with schools and educators to connect learning to the natural world. Its team consists of Vena Kapoor, Roshni Ravi and Labonie Roy, who develop culturally relevant and robust nature learning resources, which correspond to the primary school environmental studies curricula. They also engage in capacity building for teachers and educators.

MY EXPERIENCES WITH A POTOMETER

KISHORE PANWAR

How does water from the soil reach the farthest extremities of a plant? And how fast does it travel there? A device called potometer can be used to explore these questions. But conventional potometers are expensive & difficult to set up. How do we make a simple low-cost one to encourage student experimentation?

The movement of water from the soil to every part of the plant body is an essential aspect of plant physiology. This flow is driven by the loss of water from leaf surfaces through transpiration (see **Box 1**). The faster the transpiration, the faster is the flow of water through the plant body. Is it possible to estimate the rate of transpiration? Do environmental factors influence this rate? These questions can be explored through a special device called the **potometer.**

How does a potometer work? We know that the volume of water that a plant absorbs from the soil over a period of time is nearly equal to the volume it loses by transpiration in the same duration (see **Box 2**). A potometer estimates the rate of transpiration indirectly by measuring the rate of uptake of water by a leafy stem.

Commonly used potometers

Commonly available potometers are of three types – Darwin's, Farmer's, and Ganong's (named after the scientists who designed and used them for the first time). All three consist of glass tubes fitted with rubber corks.

(a) Darwin's potometer: This is the simplest of the three types. It has a U-tube type attachment along a straight glass tube fitted with a cork. A capillary tube is fitted with a cork at the base of the straight glass tube. A small 15 cm scale is tied over the capillary tube. The entire set-up is placed over a vessel containing water in such a way that

Box 1. Why study transpiration?

A large part of any plant is made up of water. For example, 98% of the body of an aquatic plant, 95% of the body of a fleshy land plant, and 80% of a woody land plant is composed of water. Surprisingly, observations show that only about 2-5% of water absorbed by the roots of a plant is used for life processes like synthesis of food, growth, and digestion. The remaining 95-98% is lost as water vapor, mainly from the leaves. This process of loss of water as water vapor through small pores, called **stomata**, on the surfaces of the aerial parts of plants (like the leaves) is called **transpiration**.

Transpiration replenishes resources required for other life processes. Since stomata are almost at the extremities of water-conducting tissues in plants, the constant loss of water vapour from these pores causes a vacuum in the vessel-like tissues. This leads to the rapid movement of water with dissolved minerals (some of the raw materials for photosynthesis) from the roots to all chloroplast-containing cells — even those at the extremities of the tallest of plants (see **Fig. 1**).

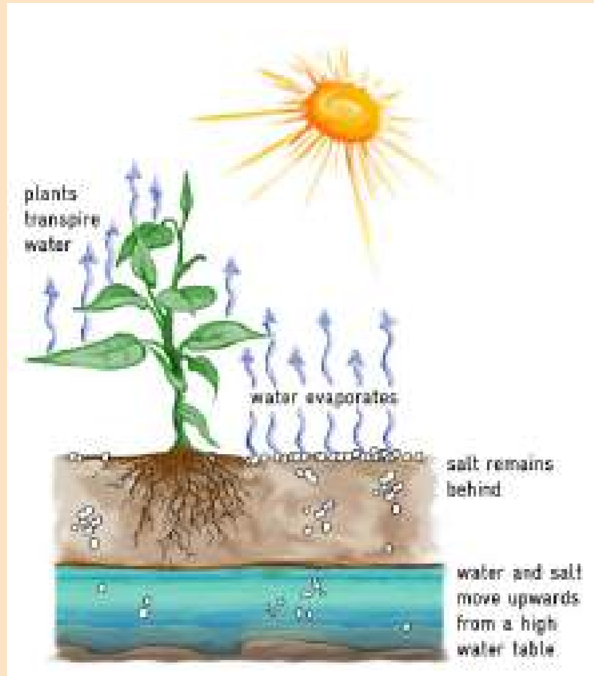


Fig. 1. Transpiration drives the movement of water through every part of the plant body.

Credits: s gendera. URL: https://www.flickr.com/photos/sgendera/8058464569. License: CC-BY.

In addition, this process plays an important role in the maintenance of the water cycle. It contributes about 10% of the water returning to the water cycle.[1] According to the forester Peter Wohlleben: '... cloud formation in areas far from the sea may be attributed to transpiration loss by plants...'[2] Interestingly, environmental factors like temperature, wind, light conditions and humidity can influence the rate of transpiration and, thereby, the rates of photosynthesis and water uptake. Therefore, studying the rate of transpiration has important implications in agriculture and water management.

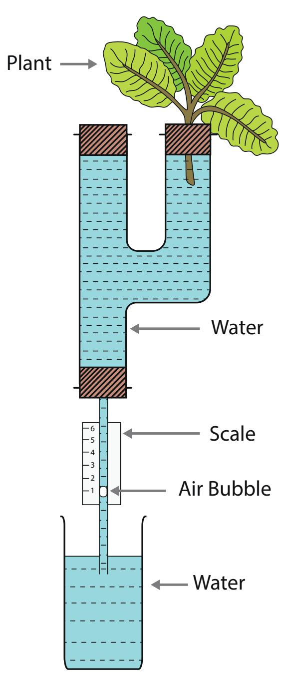


Fig. 3. The set-up of the Darwin's potometer.

Adapted from: https://www.biologydiscussion.com/experiments/top-13-experiments-on-transpiration-plants/56605.

the capillary tube just dips into the water. This set-up is ready to use once it is filled with water, and a freshly cut twig is inserted into the single hole in the cork in the side tube. The rate in transpiration can be measured by recording the upward movement of water in the capillary tube (usually visualized with an air bubble in the capillary tube or a dye added to the water) as the water gets pulled up by the twig. Since each of the corks used in this type of potometer has a single sealed hole, the risk of water-leakage is minimum. However, the apparatus requires the support of a burette stand. If a large-sized leafy twig is used for the experiment, the apparatus may still topple over (see **Fig. 3**).

(b) Farmers' potometer: This type of potometer has a large, wide-mouthed bottle fitted with a cork with three holes. A capillary tube bent in three places is fitted into one of the holes of the cork. A 15 cm scale is attached to part of this capillary tube. A funnel-like reservoir, inserted into the second hole of the cork, enables entry of water into the bottle. A freshly-cut twig is inserted into the third hole of the cork. As soon as this apparatus is filled with water, the process of transpiration starts. As soon as the volume of water in the capillary tube reduces, its open lower end is instantly placed in a small beaker. Due to this, an air bubble enters the capillary. The rate of loss of water due to transpiration is measured in terms of the rate of movement of the air bubble as the water gets pulled up by the twig. Since the bottle of water is large and heavy, it doesn't topple over and does not require a stand for support. On the other hand, the single cork with three holes makes it difficult to keep it airtight (see **Fig. 4**).

Box 2. How are the rates of uptake and loss of water by a plant related?

Leaves are the main sites of photosynthesis in most green plants. Photosynthesis occurs within clusters of cells, located between the upper and lower surfaces of a leaf, that contain (the green pigment) chlorophyll. A network of fine tubular structures, which we call **venation**, replenish these cells with minerals and water absorbed from the soil by the roots of the plant. Interspersed between these cell clusters are air spaces that allow the easy exchange of gases with the environment. These air spaces open out through thousands of stomata on the upper and lower leaf surfaces. By enabling the continuous diffusion of air and water through the leaf, each stoma allows photosynthesis, respiration, and transpiration (see **Fig. 2**).

During transpiration, water moves out from leaf cells into the environment in the form of water vapour. This causes a deficit of water in the leaf cells, which results in a transpiration pull that reaches adjoining fine veins, and through them to larger and thicker veins, finally reaching the leaf stalk. The force of this pull reaches the stems of plants, extending all the way down to the roots. This causes water to be conducted from the roots of the plant, via its stems, to its leaves.

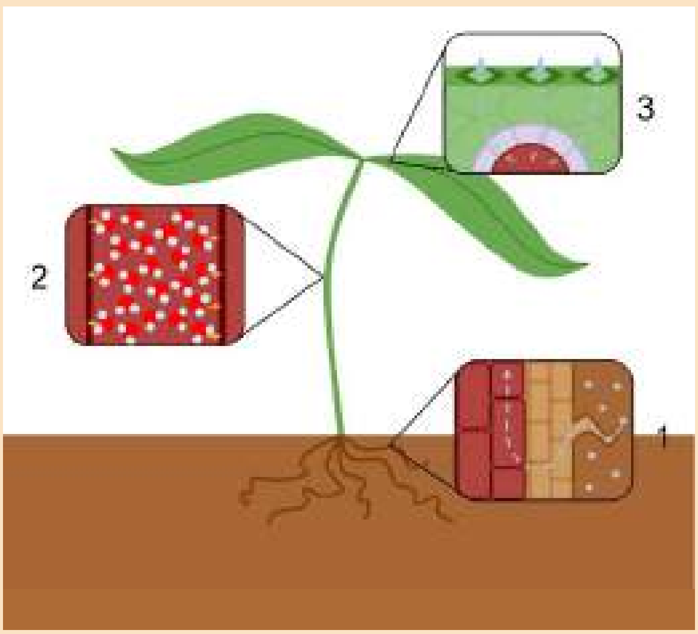


Fig. 2. The rate of water uptake by plant roots is nearly the same as that of water loss by its leaves. 1) Water molecules enter the roots passively and are guided to the xylem tissue (the water-conducting vessels in plants). 2) Once the water (red circle with two blue dots, representing H_2O) has entered the xylem, the interactions of the water molecules with the sides of the vessel (adhesion) and with each other (cohesion) leads to the formation of a column of water that extends from the roots to the top of the plant. 3) Water from the xylem is let into the spongy tissue in the leaves, where it can come into contact with stomata. When the stomata are open, the cells in this layer are exposed to the outside air, and evaporation occurs. When water molecules evaporate out of the stomata, they create tension in the water column as the forces of cohesion pull nearby molecules up with them. This creates a pulling force down the length of the xylem, causing the water in the soil to be pulled up.

Credits: Laurel Jules. URL: https://commons.wikimedia.org/wiki/File:Transpiration_Overview.svg. License: CC-BY-SA.

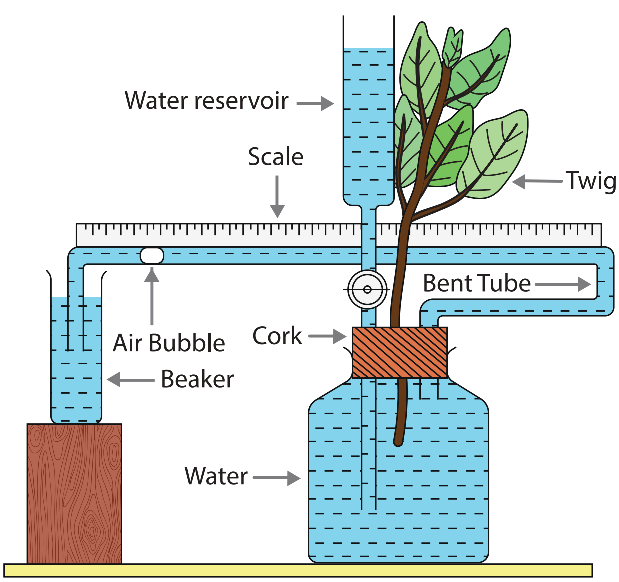


Fig. 4. The set-up of the Farmers' potometer.

Adapted from: https://www.biologydiscussion.com/experiments/top-13-experiments-on-transpiration-plants/56605.

(c) Ganongs' potometer: This is the most well-designed type of potometer. It consists of a glass tube bent at two places, with calibrations on the lower horizontal part. The upper portion of this tube has a broad opening, fitted with a single-holed rubber cork. A freshly-cut twig can be inserted into the cork. A reservoir fitted with a stopper is attached to the upper horizontal part, just before the calibrated tube. This can be used to control the movement of an air bubble inserted into the horizontal part of the tube. Like the Darwin's and the Farmer's potometers, the rate of loss of water due to transpiration is measured in terms of the rate of movement of the air bubble as the water gets pulled by the twig. The calibrated capillary tube eliminates the need to attach a scale to the device. However, the device is so fragile that it often breaks even while it is being set up. Its small base increases the probability of the apparatus toppling over (see **Fig. 5**).

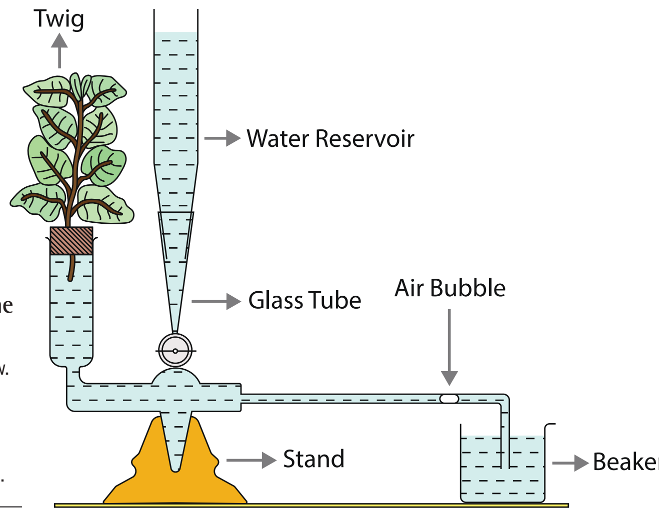


Fig. 5. The set-up of the Ganong's potometer.

Adapted from: https://www.biologydiscussion.com/experiments/top-13-experiments-on-transpiration-plants/56605.

Designing a low-cost, water-tight potometer

Potometers can be very useful in encouraging student-led investigations into the concept of transpiration and factors, like temperature or light conditions, that can influence its rate (see **Fig. 6**). But conventional potometers do not lend themselves to handling by students — they are quite expensive, difficult to set-up, unreliable, and prone to breakage.

Many of the challenges of commonly used potometers can be bypassed by using a simple, low-cost potometer (see **Fig. 7**). This can be designed using an empty plastic bottle (that would otherwise go waste) and plastic tubes instead of glass bottles, glass tubes, and rubber corks. How do we build such a device? Carve two circular holes into a plastic bottle cap with a large thick needle or knife. Into these holes, insert two 5 cm long tubes, like the water tubes used in an aquarium or the petrol tube used in a scooter or motorbike. This insertion is to be done in such a manner that half of each tube is inside the bottle, while the other half is outside. Fill the bottle to the top with water and close the cap tightly. This will cause the water to rise to the top in both tubes. If it doesn't rise, then the tubes need to be filled to the brim with the help of a syringe. Once this is done, insert the leafy stem of a berry, guava, peepal, or gerbera plant (with its petiole cut under water) into one of the tubes. Attach a scale to the bottle, close to the tube with the stem, to measure the movement of water (visualized by an air bubble) up the tube. The potometer is now ready to use (see **Fig. 7**). Do keep in mind that the lumen of the tube in which plant material is to be inserted should be selected according to the

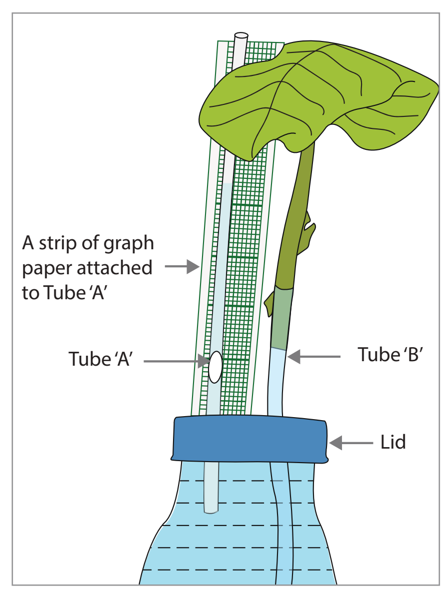


Fig. 7. A simple low-cost potometer made with a plastic bottle. In order to measure the rate of transpiration by this instrument, a strip of graph paper or a small part of a plastic scale (about 2 cm) can be attached behind tube A with cello tape. This can be used to measure the rate of movement of the air bubble in tube B.

Credits: Kishore Panwar. License: CC-BY-NC.

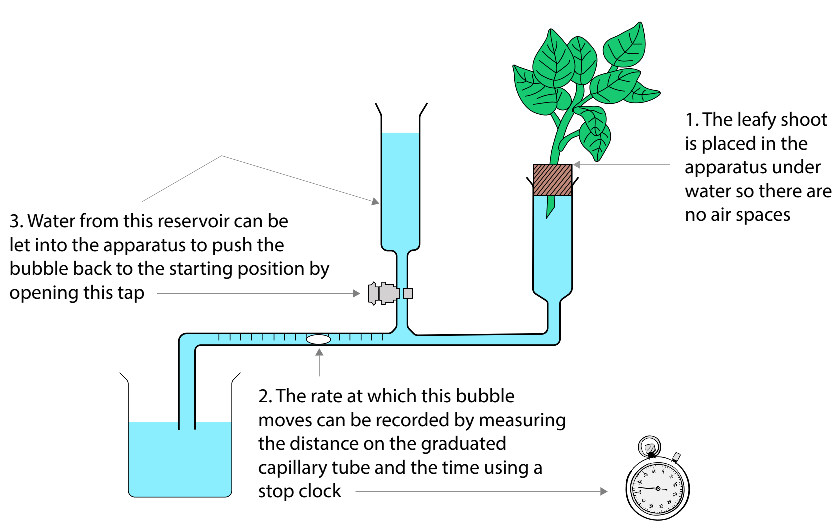


Fig. 6. Measuring the rate of transpiration.

Adapted from: Ms Cooper's IGCSE Biology. URL: https://www.youtube.com/watch?v=I510WIjaAZk.

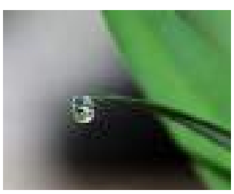
thickness of the stem or the petiole of the leaf.

How do we keep this device water-tight? Books often suggest the use of plasticine or grease to seal all openings from which water could leak. However, our experience suggests that grease does not stick to a wet surface. Instead, the tube end with a freshly-cut stem can be made water-tight by simply choosing a stem that is slightly thicker than the diameter of the opening in which it should be pushed through and fitted.

Parting thoughts

Exploring the concept of transpiration through experiments involving measurements of the rate of uptake of water by a leafy plant is an important part of the science syllabus at the higher secondary level. Due to challenges in setting up and using the three commonly available types of potometers in the science classroom, this experiment is often demonstrated by a teacher rather than performed by students. By using a simple, low-cost potometer, teachers can bypass these challenges and offer their students the opportunity to perform these experiments themselves.

Key takeaways



- Water uptake by plants is driven by the loss of water from its leaf surfaces through a process called transpiration.
- The rate at which a plant absorbs water from the soil is nearly equal to the rate at which it loses water by transpiration. This rate is influenced by environmental factors like temperature, light conditions, wind speed, and humidity.
- Potometers are special devices used to estimate the rate of transpiration by measuring the rate of water uptake through a leafy stem.
- Commercial potometers are expensive, cumbersome to use, and involve glass components that break easily, making them unsuitable for handling by students in a classroom.
- Making a simpler and cheaper potometer using plastic bottles and tubes makes it easier for students to use these devices for experiments around transpiration.

Note: Source of the image used in the background of the article title: https://pixabay.com/photos/drop-of-water-drip-water-macro-2356282/. Credits: Pitsch, Pixabay. License: CC0.

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AND THEY TOOK A DEEP BREATH!

As children grow older, they try to make sense of their world in a variety of ways. Some of their understanding develops as a result of their own observations; things they overhear their parents or other family members say; conversations with friends; and their exposure to popular media. Teachers and textbooks also add to a child's repertoire of knowledge. However, often, the understanding children develop through their real-world experiences is different from what they learn in the classroom. School education rarely addresses these dual, parallel understandings.

We developed a module on respiration to identify student conceptions, and use these as the base to build a better understanding of the concept. The teacher started the class by asking students to take a couple of deep breaths. After some initial hesitation, the children played along.

"Do we breathe air or oxygen?" she asked them.

The class responded with a resounding answer. *"Oxygen"*, they said.

She asked, *"But, last year, we learnt that air is a mixture of many gases, right? So, how do we breathe just oxygen then?"*

This puzzled the children. After brief thought, one student responded, *"The hair in our nose helps us to separate oxygen from air".*

Another student responded, *"But oxygen is much smaller. The hair inside the nose traps only large particles."*

Both had reasons for believing what they did. They started building hypotheses about how we could breathe just oxygen from the mixture of gases in the air. Many students supported each perspective. This resulted in an argument, with each side offering examples and counterexamples. It was a pleasure to see the students thinking, arguing and, most importantly, being engaged in a scientific discussion — an opportunity that seldom arises in conventional teaching.

At this point, a girl who had remained silent throughout raised her hand, and said, *"But pure oxygen is flammable. If we breathe in pure oxygen, won't there be a fire inside us?"*

Another student pointed out that *"If we could purify air and breathe just oxygen, we wouldn't need to wear pollution masks, and the problem of air pollution would have been solved!"*

Instead of just throwing facts at her students, the teacher led students through more detailed observations and thought experiments to test their hypotheses. For example, to address the hypothesis that the nose could filter oxygen from the mixture of gases in air, the teacher shared an image of the inner part of the nose. This showed the absence of the physical apparatus for such a filter. The teacher also took the opportunity to point out the need to revise or modify our hypotheses when our observations and the results of our experiments don't match it. After much deliberation and with the help of their teacher, the children arrived at the conclusion that we inhale air, and not just oxygen.

After this intense discussion, the teacher allowed the class some time to settle down. Then she asked them the next question, *"How do you think we breathe?"*

Interestingly, most students believed that our nose has a muscle that helps us suck air. Smiling gently, the teacher asked them to observe their breathing more carefully and record their observations. A few students said that they had observed their chest expanding. Others shared that they could feel the cold air gushing in through their nose. A few students remarked on how their nose muscles did not seem to move much during the process of breathing. Everyone seemed puzzled about how we inhale and exhale so much air.

"What is regulating this?" the teacher asked again.

There was much discussion amongst the students, but they could not arrive at an answer. Sensing the frustration building up in the classroom, the teacher reminded them about a recently learnt chapter on wind. *"Do you remember how wind moves?"* she asked.

Many students quickly shared responses to suggest that wind moved from *"high pressure to low pressure".*

"Right! Now can you think of a mechanism for breathing?" the teacher asked.

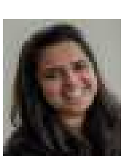
"Yes!" a student responded with excitement. *"When the pressure outside is high, air will go into our body. And when the pressure outside is low, air will rush out."*

His friend immediately contradicted this, *"How can pressure around us change every few seconds?"*

"What do you all think?" asked the teacher, looking around the class. Seeing the class re-engage in spirited discussion, she beamed with joy.

After pondering on the teacher's question for a while, one of the boys suggested that, *"The pressure inside our body changes. That will help to push and pull air."*

The class was now close to finding out the actual mechanism behind breathing. Through an experiment using two balloons connected to each other with a T-joint enclosed in an empty bottle, and an elastic to pull its base, they quickly figured out how pressure inside a cavity can change. Together, they finally deconstructed the mechanism of breathing. Happy with this, they took a deep breath.



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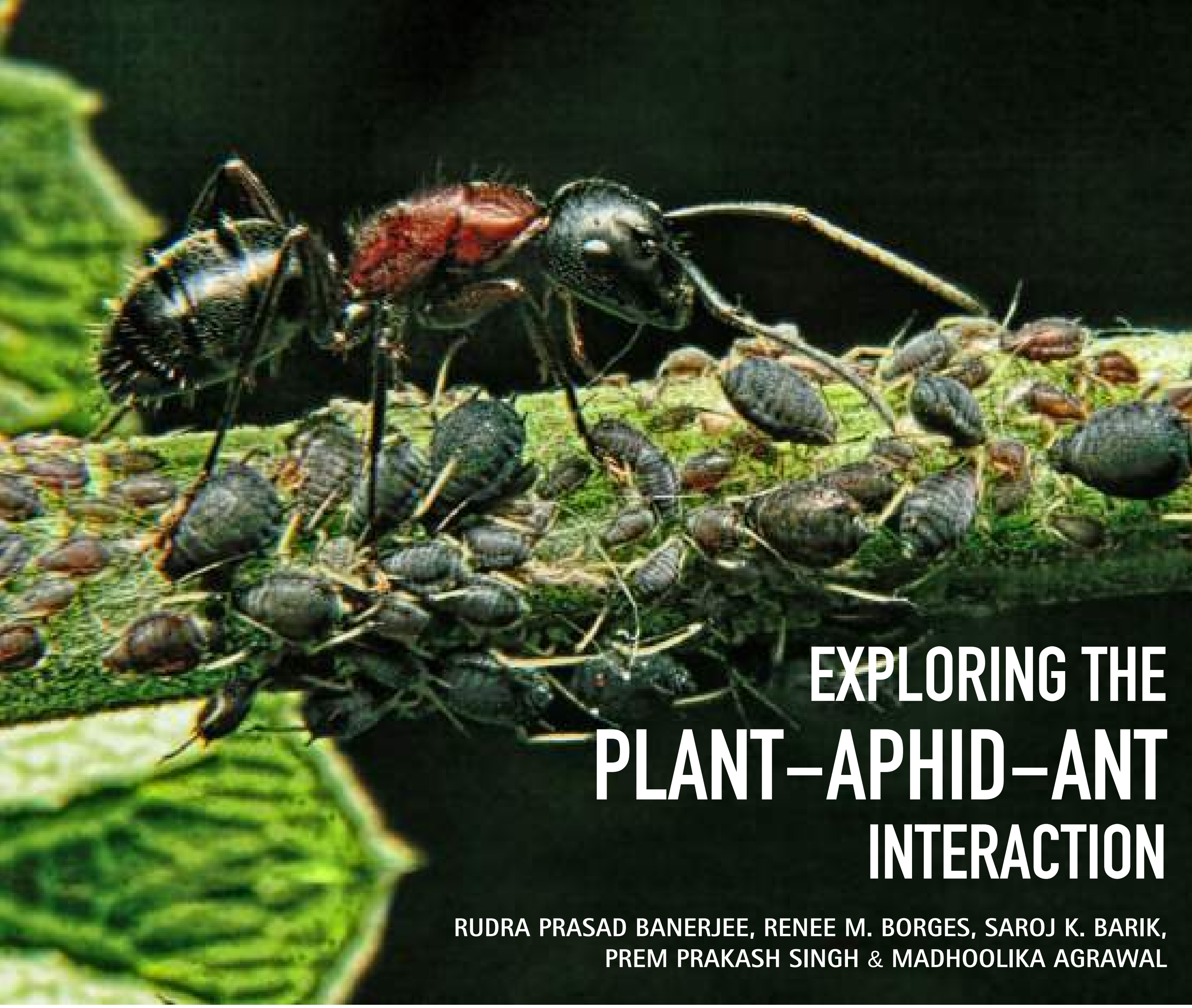


EXPLORING THE PLANT–APHID–ANT INTERACTION

RUDRA PRASAD BANERJEE, RENEE M. BORGES, SAROJ K. BARIK, PREM PRAKASH SINGH & MADHOOLIKA AGRAWAL

Different species interact with each other in complex and diverse ways. Why and how do we study these interspecies interactions? How do we introduce students to these interactions through real-world observations of plants, aphids, and ants from their own backyards?

Children begin observing and wondering about interspecies interactions in and around their home and school long before their science textbook introduces them to related concepts. Giving students the opportunity to study some of these interactions may help teachers connect abstract concepts in the textbook to real-world observations from their backyard. For example, have you come across a plant in your garden, school compound, or fields that seems to be covered with tiny creatures? Does it look like these parts of the plant are bustling with ants? If your answer to both these questions is 'yes', then you may be at the right place to witness a fascinating three-way interaction between ants, aphids, and plants (see **Box 1**).

The plant–aphid interaction

As you may have guessed, the tiny white, yellow, green, or black creatures are insects called aphids (see **Fig. 1**). Like mealybugs, whiteflies, and plant hoppers, aphids have needle-like mouth parts (called **stylets**) that they inject into the tender parts of the plant to feed upon the **phloem sap** that the plant makes for its own nourishment (see **Box 2**).[1] The loss of nutrition caused by these **phytophagous** (*phyto* = plants, *phagy* = to eat) or sap-sucking insects, affects the health of the plant, and causes wilting and yellowing of its parts. It may also affect the reproductive fitness of the plant, reducing its fruit and seed set.

Box 1. Finding and observing plant–aphid–ant interactions:

Interactions among plants, aphids, and ants are often opportunistic or facultative in nature. This means that ants may or may not form associations with the aphids throughout the year. The aphid–ant association is strongly dependent on the availability of food resources, seasonality, requirements of the ant colony, and phenology of the host plant (changes in the timing of seasonal events like bud bursts, flowering, and fruiting). Since the environmental conditions in winter limit the activities of aphids and ants, such interactions are best observed in summer (March/April–July) and post-monsoon (September/October–November). While such interactions may be difficult to observe on high branches or tall trees, they can be easily observed on 3-5 m tall plants or on branches at a lower height. Looking for ants on plant parts and tracking their movement can help provide important clues to the location of such interactions. Many a time, aphid infestation can also be seen on the apical portions of host plants. Once such an interaction is identified, the plant–aphid–ant interaction can be observed for a variety of features (see **Checklist for observation of plant–aphid–ant interactions**).

Fig. 1. Aphids inject their needle-like mouth parts into their host plant to feed on their phloem sap.

Credits: Kent Loeffler, US Department of Agriculture, Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Schizaphis_graminum_usda_(cropped).jpg. License: CC-BY.

Aphids may also act as vectors of deadly plant viruses such as cucumber mosaic virus and potato virus. These viruses can enter their host plant through the saliva of a feeding aphid. Weakened by the aphid infestation, the plant becomes more susceptible to these and other diseases. Since the aphid benefits at the expense of the plant, the plant–aphid interaction offers a real-world example of an antagonistic (parasitic) interaction.

The aphid–ant interaction

While the aphids feed on phloem sap, they excrete droplets of a sticky, sugary, nutrient-rich liquid, called **honeydew,** from their rectum. This attracts certain species of ants to the host plant. How? Studies show that these ants 'smell' the presence of certain **volatile organic compounds** (VOCs) in the honeydew through sensory organs called olfactory lobes that act like our nose (see **Box 2**). These VOCs are produced by the action of specific bacteria that reside in the inner gut wall of the aphids.[2] The ants feed on the honeydew, and herd and tend to the aphids (see **Fig. 2**). Some ant species also deter the **natural enemies** of aphids (see **Box 2**).[3,5] These could include the larval and adult stages of insects such as ladybird beetles, hoverflies, and parasitic wasps that either feed on the aphid or lay eggs within its body (see **Fig. 3**). Since both

Box 2. Glossary:

- **Phloem sap:** A nutrient-rich food resource produced in plants. The name is derived from the mode of transportation that occurs through the phloem (a pipeline for transporting food across different parts of the plant). Rich in sugars and amino acids, it provides nourishment for the growth and development of the plant.
- **Volatile Organic Compounds (VOCs):** Chemical compounds that rapidly evaporate on contact with air. Secreted by organisms during interspecies interactions, these chemicals help in interspecies communication.
- **Natural enemies:** The organisms that prey on or parasitize a particular species.
- **Myrmecophilous aphids:** Derived from the combination of two words – *myrmeco* meaning 'ants', and *phily* meaning 'loving', this term refers to aphid species that are tended to by ants.

Fig. 2. Some ants extract and feed on the honeydew secreted by aphids.

Credits: Jmalik. URL: https://commons.wikimedia.org/wiki/File:Ant_feeding_on_honeydew.JPG. License: CC-BY-SA.

partners benefit from this association, the aphid–ant interaction offers a real-world example of mutualism.[3, 4, 5] This type of mutualism is referred to as 'food for protection' mutualism.[5]

However, like many other interspecies interactions, the ant-aphid association is more complex and dynamic than it may seem. Most ants are opportunistic foragers — eating almost anything they can find to fulfill the needs of their colony. This may lead one to wonder if ants also prey on aphids? They do, when their protein requirement exceeds their carbohydrate requirement (which can be met by honeydew). Under such circumstances, the aphid–ant interaction changes from being mutualistic to becoming antagonistic. However, studies also suggest that ants prefer to prey upon aphid species that are non-myrmecophilous rather than those that are **myrmecophilous** (see **Box 3**).[6] This raises the question — how do ants distinguish between the two kinds of aphids? Studies suggest that the body odor of every aphid has species-specific chemical signatures known as **cuticular hydrocarbons** (CHCs). Depending on the nature of these CHCs, the relationship between an aphid species and its tending ant species may be obligatory (both species depend entirely on, and cannot survive without services from each other) or facultative (the ant species is partly dependent on the aphid species). CHCs also help a partner ant species to differentiate between myrmecophilous and non-myrmecophilous aphids.[7]

Fig. 3. Some ants protect aphids against their natural enemies.

Credits: JerzyGorecki, Pixabay. URL: https://pixabay.com/photos/ants-aphids-kennel-leaf-macro-1271768/. License: CC0.

Box 3. Identifying the ant and myrmecophilous aphid species in your backyard:

For ants, these may be helpful: http://www.antkey.org/en and https://www.antweb.org/.

For aphids, check these out: http://aphid.aphidnet.org/credits.php or https://influentialpoints.com/Blog/How_to_identify_aphids_from_photos--the_basics.htm

The plant–ant interaction

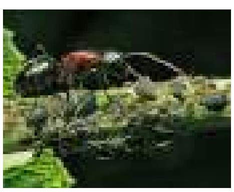
Recent studies on interactions between plants, ants, and aphids have shown that some species of ants protect the host plant against other non-sap-sucking insect herbivores such as caterpillars and beetles.[8] Other studies show that accumulation of honeydew can attract fungal infection. By cleaning plant parts of honeydew, ants protect the host plant against these infections.[9, 10] This suggests that despite the harm caused by aphids to the host plant, the presence of protective ants might save the plant from further damage.

Parting thoughts

Detailed studies on interspecies interactions like the plant–aphid–ant interaction have helped reveal the dynamics and complexity of such interactions in general, as well as their role in maintaining ecological balance. For example, several studies show that when ants are blocked from access to aphids (using a sticky insect barrier, like Tanglefoot), aphid colony size reduces. This also causes an increase in abundance of the natural enemies of aphids and herbivory on host plants, which reduces both aphid and host plant fitness. The excluded myrmecophilous ants tend to show a preference for insect prey, suggesting a shift from carbohydrate-seeking to protein-seeking foraging behaviour.

Introducing students to some of the most interesting insights that ecologists have learnt about plant–aphid–ant interactions through scientific investigation can spark their interest and curiosity in related life science topics from their curriculum. It can also strengthen and expand their understanding of the nature and process of scientific inquiry.

Key takeaways



- Real-world observations of plant–aphid–ant interactions in their immediate surroundings can be used to introduce students to textbook concepts around interspecies interactions and their role in maintaining ecological balance.
- The plant–aphid relationship offers a relatable example of an antagonistic interaction, while the aphid–ant relationship offers a fascinating example of a mutually beneficial interaction.
- Since the aphid–ant interaction remains mutualistic only as long as the benefit that the ant gains from it is high, the context-dependent nature of this interaction can be used to illustrate the complex and dynamic nature of interspecies interactions.
- Sharing details of the kind of experiments used to understand these interactions can help expand student understanding of the nature and process of scientific inquiry.

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CHECKLIST FOR OBSERVATION OF PLANT-APHID-ANT INTERACTIONS

1. What is the habit of the host plant?
    - Herb
    - Shrub
    - Tree

2. What is the developmental stage of the host plant?
    - Vegetative
    - Reproductive (Flowering/Fruiting)

3. Which portion of the plant is infested with insects?
    - Mature branch (brown in color)
    - Young apical branch (greenish in color)
    - Flower
    - Fruit

4. Which of these species can you see in interaction with the plant?
    - Only ants
    - Only aphids (or other hemipteran insects)
    - Both

5. Which of these ant behaviours do you observe?
    - Aggregating near the aphid-infested parts of the host plant
    - Rapid movement across other parts of the plant
    - Both

6. How do the aphids look?
    - Cottony white
    - Yellowish or greenish, with tiny, pear-shaped bodies, sometimes transparent
    - Brown or black with horn-like appendages on the head

7. Did you find any other insects beside ants and sap-sucking insects?
    - Yes
    - No

8. If you answered yes to the previous question, what kind of insects did you notice?
    - Caterpillars (larva)
    - Mature adults

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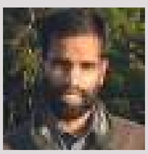

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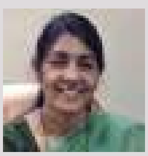

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OBSERVING LIGHT: SHADOWS & REFLECTIONS

RAJARAM NITYANANDA

Are shadows completely dark? Does the human eye have anything in common with a mobile phone camera? How many mirrors do we need to see our right hand appear as it would to others? This article explores many simple ways of teaching concepts related to 'light' by linking them with everyday observations on shadows and reflections.

It is always a challenge to build curiosity, motivation, and a basic understanding of any topic in science. A popular worldwide trend is to bring in technology — computer animations and demonstrations, with specially designed equipment. This trend attempts to overcome the sense of familiarity and boredom, which comes with early exposure to mass media and the internet, and is now catching on in schools in India.

There is no doubt that technology has value in creating interesting learning experiences. But this article is about the oldest technology — live (meaning not virtual) observation. Simple observations are not a second-best option that one engages with because of a lack of online or lab resources. They are valuable even to students who have access to virtual resources, because ultimately science is about the real world. First-hand experiences can help a student connect to the more abstract developments that school science must cover in later years. Without such a connection, even students who do well in existing school systems may find it difficult to apply what they learn from books and lectures to new situations. Even if one first learns the theory, it really helps to see it being put into practice, and use observation to build connections. The observations suggested here are not just for students in middle school, but for anyone, teachers included, who has not tried them.

Light appears early in the school science curriculum. This is natural — vision is one of our most powerful senses. Two basic topics under light — shadows and reflections — are covered in all textbooks, with the usual ray diagrams showing light travelling in straight lines from the source. This is already a virtual experience — students do not always connect the figures with what they see, but know that the diagrams have to be reproduced in tests and interviews. However, studying light can be an opportunity for teachers to enthuse students about science by building connections to observations that they can themselves make and think about. How do we do this?

Shadows — not completely dark!

One way to think about the shadow of an object, say a duster, is to imagine what a small creature, say an ant, sitting on a wall would see if it were at different positions with respect to the duster and the Sun (see **Fig. 1**). If a point on the wall is dark, it means that the ant sitting there finds that the Sun is completely blocked by the object. As we move it away from this point on the wall, we notice that the edge of the shadow of the duster is not sharp. This observation is what illustrates the so-called **penumbra**. 'Penumbra' is just a name. Isn't it better to say that as the ant crawls past the edge of the shadow of the duster, it moves from the region where the Sun is completely covered, to one where it is partially covered (the penumbra), and finally to one from where it can see the entire Sun?

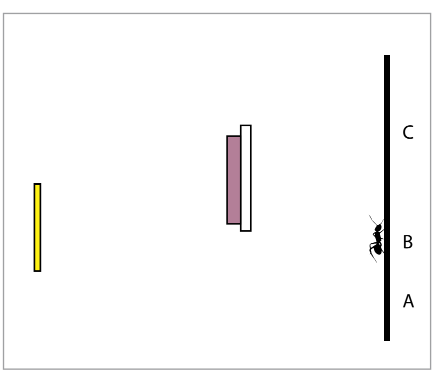


Fig. 1. Are shadows completely dark? The yellow line to the left of the image represents the Sun. When the ant on the wall is at C, it cannot see any part of the Sun. When it is at A, it can see the whole Sun. When the ant is at B, it can see that part of the Sun that lies between the darkest part and the fully lighted part. This is the fuzzy edge of the shadow.

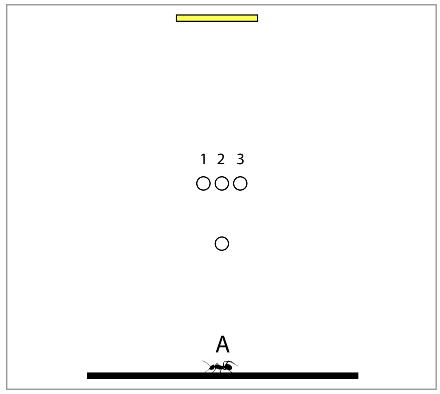


Fig. 2. Overlapping pencil shadows. When the moving pencil is at position 1 or 3, then the ant at A sees a larger part of the Sun covered. When it is at position 2, the pencils cover each other, and more of the Sun is visible. This explains the increase in light at A, when the shadows overlap.

(It is wise to imagine this, rather than actually going under such a shadow and looking at the Sun oneself. Looking directly at the Sun can damage the eye).

Another experiment you can do with this method surprises even practicing scientists. Hold two pencils in the near noon sun in such a way that their shadows fall on the ground more than a metre away. By moving one pencil over the other, you can make the shadows overlap or come apart. You'll notice that the shadow is darker just before and just after the overlap, and becomes brighter when there is a full overlap. Similarly, when you hold the pencils crossed, the darkest portion of the shadow is not at the intersection, but on either side. Again, looking at this from the point of view of an ant is a useful exercise. The darkness of the shadow in each of these cases depends on how much of the Sun the ant can see (see **Fig. 2**).

What lies between the shadows?

Let us now look at the opposite of a shadow. When light passes through a hole in a piece of cardboard, we get a bright region inside the shadow. We expect a square hole to give us a square patch of light, a triangular one to give a triangular patch, etc. This is what we see when we place the cardboard close to the wall. But when the hole is small (say about 3 millimetres in size), something interesting happens as we move away from the wall. At a distance of about half a metre, the patch of light starts looking more circular. At a distance of about a metre, we see an almost circular disc, even though the hole may have been a triangle. What's more — the size of the bright patch starts increasing. As you may have guessed, the circular patch is an image of the Sun (see **Fig. 3**). This observation is the basic principle behind a pinhole camera. Students can easily make this simple toy for themselves (see **Box 1**).

We can see this pinhole experiment occurring naturally in the shade of a tree. This explains why the Sun, shining through irregularly shaped gaps between the leaves of a tree, leaves circular patches of light in the shade. During a partial eclipse of the Sun, which can be seen from most places in India about once every decade, the circles become crescents (see **Fig. 4**). This makes it clear that we really are seeing images of the Sun.

Another interesting aspect of shadows is revealed when one looks at the Moon through binoculars (even though

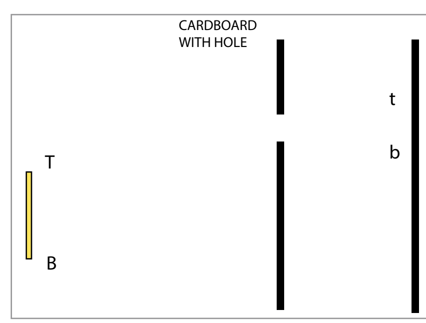


Fig. 3. How a small hole in a piece of cardboard makes an inverted image of the Sun. The point t on the upper side of the wall receives light from B, the bottom of the Sun. The point b on the lower side of the wall receives light from T, the top of the Sun. This arrangement only works if the hole makes an angle smaller than that of the Sun as viewed from the wall. If the hole is very close to the wall, the lighted portion on the wall takes the shape of the hole.

Box 1. Using a pinhole camera to introduce the human eye:

A pinhole camera is a good way of introducing students to the workings of the human eye, the basic tool for all our observations. The eye is a beautiful collector of light which shows the brightness and colour of light from all directions. This is what we call a picture or image. In fact, the camera in mobile phones, which many students will be familiar with, is more like the eye than earlier film-based cameras. It has a human retina-like chip. This is connected to a computer through wiring that resembles the optic nerves going to our brain. The computer has software to turn the upside-down picture right-side up. Our brains seem to have this as well.

Fig. 5. Shadows on the Moon.

(a) A photo of the full Moon. Notice that we don't see any shadows even though there are mountains and valleys.

Credits: Gregory H. Revera. URL: https://en.wikipedia.org/wiki/File:FullMoon2010.jpg. License: CC-BY-SA.

(b) A picture of the half Moon. Note the clear shadows near the boundary between the lighted and dark part. An observer located there would see the Sun close to the horizon and, hence, shadows would be long.

Credits: Luc Viatour. URL: https://commons.wikimedia.org/wiki/File:The_Moon_Luc_Viatour.jpg. License: CC-BY-SA.

moonlight is much weaker than sunlight, one should be careful of the glare). Unlike the full Moon, the half Moon shows clear shadows of mountains and craters (see **Fig. 5**). To understand this, ask your students if they've observed any change in the length of their shadows in the Sun at different times of the day. We know that our shadows are long when the Sun is low on the horizon, and disappear when the Sun is overhead. Now, imagine we were sitting near the centre of the full Moon. The Sun would be directly overhead, and our shadow would disappear. The mountains on the Moon do cast shadows near the edge of the full Moon, but these are invisible when viewed from the same direction as the Sun. Since this problem does not exist at half Moon, the shadows are plain for us to see.

Doing it with mirrors

We now turn to mirrors, which fascinate most children, until they grow up and start taking them for granted. Most of us are aware that a mirror shows us a person whose left hand is like our right hand. This change is called **lateral inversion** — an unfortunate

Fig. 4. Natural pinhole optics. These crescent-shaped patches of light are images of the Sun made by natural pinholes (gaps between leaves) in the shade of a tree.

Credits: Thayne Tuason. URL: https://commons.wikimedia.org/wiki/File:Solar_Eclipse_August_21_2017.jpg. License: CC-BY.

name, because what is reversed in the mirror is the direction — left or right — in which the person is looking. Our top and bottom are not interchanged. Our languages define left and right with respect to the direction in which a person is looking, but define top and bottom with respect to the earth. This 'inversion' may seem like a point of language, but can be a matter of life and death. A surgeon operating on a patient should definitely be clear what they are referring to when they say *"left"* — do they mean the patients left, or their own?

That a single mirror does not show us as we appear to others is particularly clear to a person wearing a garment, like a sari, which goes over one shoulder, or a shirt, which has a pocket on one side. To see yourself as others see you, use two mirrors, placed at 90 degrees to each other. If you have not looked into such a set up before, it can be a strange experience to see the image moving its right hand away from itself as you move your right hand away from you (see **Fig. 6**).

It can be even stranger to look into three mirrors, each placed at 90 degrees to the other two. The geometry of this

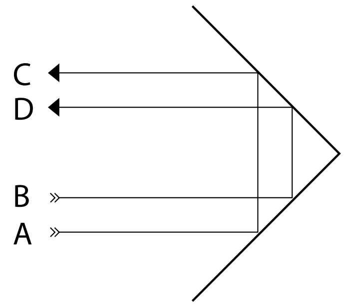


Fig. 6. Reflection from a pair of mirrors making an angle of 90 degrees with each other. As the person standing in front of the mirror moves their right hand from B to A, the hand of the reflected image (which is on the opposite side) moves from C to D. This means that it is also seen as their right hand moving away. With a single mirror, the image would appear to move the left hand in the same direction.

Credits: Rajaram Nityananda. License: CC-BY-NC.

set up would be like that of two walls and the floor meeting at the corner of a room. It is, therefore, called a **corner reflector**. The corner reflector sends any ray of light, coming from any direction, back in the same direction (see **Fig. 7**). What does one see when one looks into such an arrangement? No matter where one goes, one sees one's own eye in the corner. This is not just a curious trick, but can actually be very useful. Such reflectors are used on highways, especially near the edge of a dangerous curve. When the headlights of an approaching car illuminate the reflector, it sends light back to the driver, warning them. This is a very efficient arrangement because it needs no power, and only sends light where it is needed.

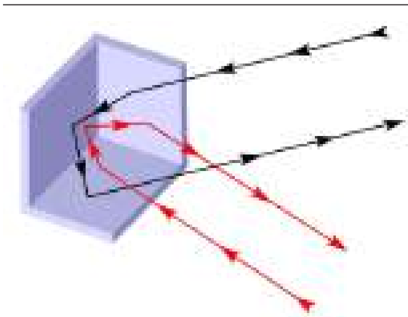


Fig. 7. An arrangement of three mirrors meeting at a corner. Light coming from any direction is sent back in the same direction.

Credits: Chetvorno. URL: https://commons.wikimedia.org/wiki/File:Corner_reflector.svg. License: CC0.

A topic as simple as reflection can play a very important role in today's space and energy technology. One dramatic example is of a corner reflector set up by American astronauts on the Moon during the Apollo mission (see **Fig. 8**). Scientists used this to send a laser beam to the Moon from a telescope on earth, and catch the returning beam with the same telescope. Since the beam was a short pulse, they were able to measure the time taken (about 2.5 seconds) for it to cover this distance and arrive at a very accurate measure of the distance to the Moon. Another interesting application of mirrors is to bring sunlight from a large area to a small one. This has been used to harness solar energy (see **Fig. 9**).

Conclusion

Today's students will live in an age of far more advanced technology than their teachers. It is likely that many of these technological advancements are likely to involve light. Even today, lasers are used for cutting in industrial applications, and correcting vision by reshaping the cornea of the eye. Light carries most of our phone conversations and internet surfing over optical fibres. Many new, wonderful, and useful things are bound to come of our understanding of light in the future too.

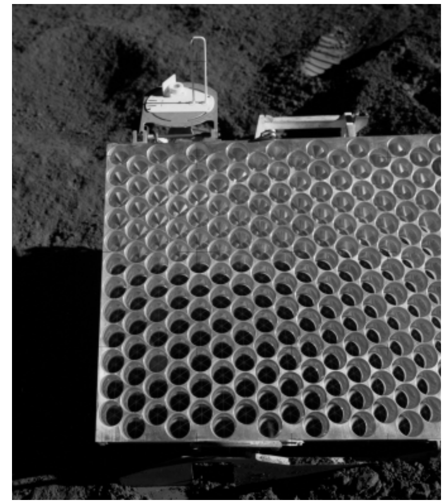


Fig. 8. A set of corner reflectors placed on the Moon by astronauts on Apollo 15. This allowed very accurate measurements of the distance to the Moon, and how it changes with time.

Credits: NASA, USA. URL: https://commons.wikimedia.org/wiki/File:ALSEP_AS15-85-11468.jpg. License: CC-BY.

Fig. 9. A power plant in Spain uses energy from the Sun, instead of coal, to produce the steam that runs its generators. Because of the dust in the air, one can actually see the path of the Sun's rays.

Credits: afloresm. URL: https://commons.wikimedia.org/wiki/File:PS10_solar_power_tower.jpg. License: CC-BY.

Students who make a career in science or engineering will learn much more about light, but everyone can appreciate some of the most basic principles of light. This article shares only some examples involving shadows and reflections, which can be used to provoke observation and discussion. Such examples are not meant to replace the textbook or classroom teaching, but rather to create some enthusiasm to understand taught concepts. When shared with students from higher grades, these experiments can help one appreciate how simple but general concepts, like those related to the rays of light, can help us understand many things around us.

Key takeaways

- The topic of light appears early in the school science curriculum since it connects to vision, one of our most powerful senses.
- While students are able to reproduce key concepts and ray diagrams in tests and interviews, they are not always able to connect these with their real-world experiences.
- Simple observations and first-hand experiences of shadows and reflections that students can themselves make and think about can provoke discussion and enthuse them about science.
- Exploring everyday applications of light-related concepts, such as pinhole cameras and corner reflectors, can help students connect to more abstract developments in the school science curriculum.

Note: Source of the image used in the background of the article title: https://www.shutterstock.com/image-photo/little-child-plays-his-self-reflection-47335690. Credits: manzrussali.

Rajaram Nityananda is currently teaching at the Azim Premji University, Bengaluru. Prior to this, he was at the Raman Research Institute (RRI), Bengaluru. He has been the Chief Editor of Resonance, journal of science education, for one term (~ three years). Much of his research work has been theoretical — in areas of physics relating to light and to astronomy and, hence, involving mathematics and/or computation. Rajaram enjoys collaborating with students and colleagues — many of them experimenters, and many outside his own institution.

GO ON, GET YOUR HANDS DIRTY!

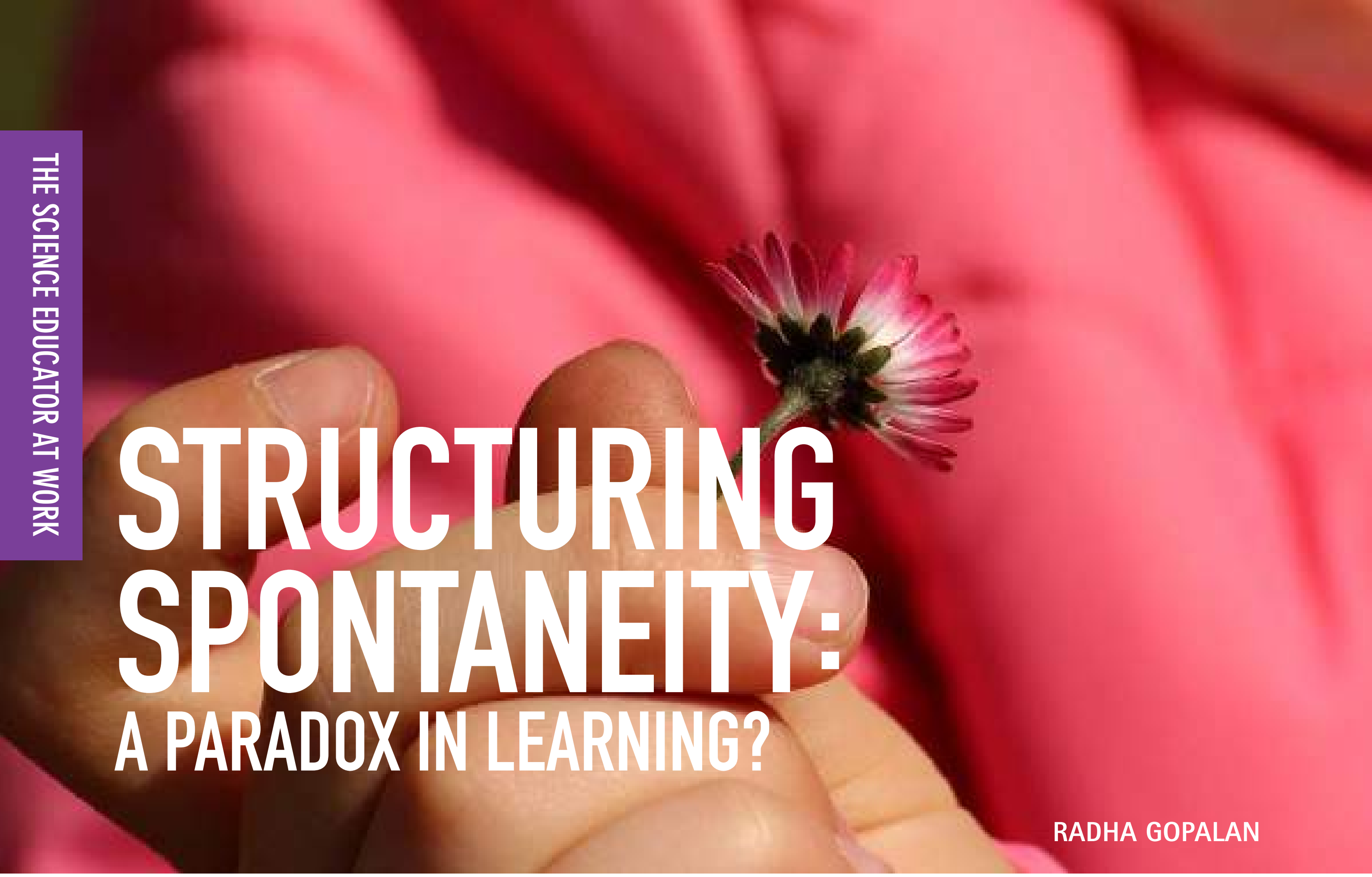
Has a bit of gardening always seemed like the perfect way to calm your mind? Well, guess what? Turns out that this belief is supported by science. Research shows that a soil bacterium called *Mycobacterium vaccae* can act as an anti-depressant in mice. Mice injected with *M. vaccae* showed higher levels of cytokines. This, in turn, leads to higher levels of serotonin production in their brains. Serotonin, as you may know, is a neurotransmitter that reduces depression and regulates anxiety.

We are likely to come into contact with these bacteria while working with healthy soils, or even inhaling it. So the next time you feel down in the dumps, remember that getting your hands dirty with a bit of gardening might actually improve your mood. In fact, even just a walk in a garden may help!

Read more here:

- Antidepressant microbes in soil: how soil makes your brain happy. URL: https://realfarmacy.com/antidepressant-soil/
- Immunization with a heat-killed preparation of the environmental bacterium *Mycobacterium vaccae* promotes stress resilience in mice. URL: https://www.pnas.org/content/pnas/113/22/E3130.full.pdf.

Ramgopal (RamG) Vallath is a motivational speaker. He is also the bestselling author of the children's science fiction, 'Oops the Mighty Gurgle'. He delivers motivational talks and science workshops in schools. He can be contacted at ramg@azimpremjifoundation.org.



STRUCTURING SPONTANEITY: A PARADOX IN LEARNING?

RADHA GOPALAN

Meaningful learning can seem effortless in spontaneous explorations. But is it possible to evoke the same wonder and curiosity in structured spaces? Is it possible to bridge the two? How do we structure learning sessions to help students arrive at scientific concepts spontaneously?

"Learning is the human activity that least needs manipulation by others. Most learning is not the result of instruction. It is rather the result of unhampered participation in a meaningful activity."

— Ivan Illich.

Much meaningful learning occurs through spontaneous, effortless immersion in one's natural surroundings, or through real-life experiences with gardening, taking care of animals, or growing food. Such explorations can nurture deep curiosity and evoke a sense of wonder. But is it possible to create such learning spaces for 12-13-year-olds in a structured space? How much structure would such spaces need, particularly if scientific concepts and skills are to be learnt? Will this structure take away from the sense of wonder that comes with spontaneity and serendipitous findings? These were some questions I grappled with while designing a learning session, for a group of middle-school students, aimed at encouraging an exploration of the diversity of life in their immediate surroundings.

Designing the learning sessions

My students lived in peri-urban areas and studied in local government schools. As these were the early days of the COVID-19 lockdown, the school premises and its natural surroundings were inaccessible. While some of the students had access to open spaces around their homes, others had a small garden, or grew flowers and vegetables on their terrace. My engagement with them was structured around six online sessions of one hour duration each, on alternate days. These sessions had two objectives — (i) to encourage students to use their senses of sight, smell, hearing, and touch to learn about their surroundings, and (ii) to explore the importance of observing with attention to develop awareness of, and therefore, sensitivity to changes occurring in their surroundings. On the days we did not meet, the students were encouraged to explore their immediate surroundings — within their houses and just outside. To keep the exploration open-ended and allow for discovery of the unexpected, the instructions for these days were kept to a minimum.

An introductory session was followed by three sessions that focused on an exploration of the outdoors — observing plants, birds, insects, and any other life in the garden, on leaves, in pots, etc. The last two sessions were focused on observing the diversity of life indoors — like spotting spiders, bag worms, ants, cockroaches, and lizards. Students were encouraged to record their observations — either by tabulating what they saw, heard (e.g., bird/ animal/ insect sounds), smelt or touched; drawing/sketching them; and/or keeping a journal that made note of the date and time at which each observation was made. The one non-negotiable instruction was to avoid taking photos. This element of structure was introduced to help students focus on observing with all their senses.

Observing the living world around us

The students had many questions at the end of our first session: *"What if we are not able to identify the plants, birds, or insects? How many birds or plants do we have to see? How do we describe bird sounds? What if I do not see any birds or insects? Do I have to get up early in the morning to see birds?"* Most of their concerns were related to what they should write and how much detail they were expected to provide. Some expressed the worry that their drawing skills *"were really bad"*. Others wondered how they would observe creatures that they were scared of, e.g., some insects and spiders. My response: "*let's give it a chance, observe what you can, and let's see what happens. We can share our experiences in the next session, and try and resolve your concerns."*

During the second online session, the students shared their first set of observations — tabulated written observations (see **Fig. 1**) as well as colourful sketches of birds, flowering plants, leaves, insects, leaf shape, colour and venation, leaf margins, and the arrangement of leaves on the stems of plants (see **Fig. 2**). Some students had written short essays on their observations. A few others had used their sense of touch to record the textures of leaves, barks of trees, and the body surfaces of beetles. At the end of this session a specific instruction was given — to revisit each location at least three times a day (morning, afternoon and evening), and take at least 15 minutes during each visit to observe and record their findings. This 'structure' (multiple observations at different times) was introduced to help students learn how to make detailed observations, as well as look for patterns and rhythms in a focused and systematic manner.

By the third and fourth sessions, there was a shift in the way some of the students shared their experiences, from one-off and direct observations to questions and comments: *"I did not realise there were so many different kinds of butterflies. They sit still for so long on not just flowers but also on leaves. What do they get from leaves? Why do birds sit on wires? Why do we see birds mostly in the mornings and evenings? What happens to them in the afternoon? Do they have an internal clock? Why do birds visit only certain trees? Insects are so good at camouflaging themselves. I did not realise that there could be so many different kinds of insects, particularly ants, in a small patch of ground. Why are there different coloured leaves on the same plant? Only after these few days I realised that there are lots of noises at night — are they made by insects or owls? I feel so bad that I have been ignoring all this nature that exists in my garden. If there is so much happening in*

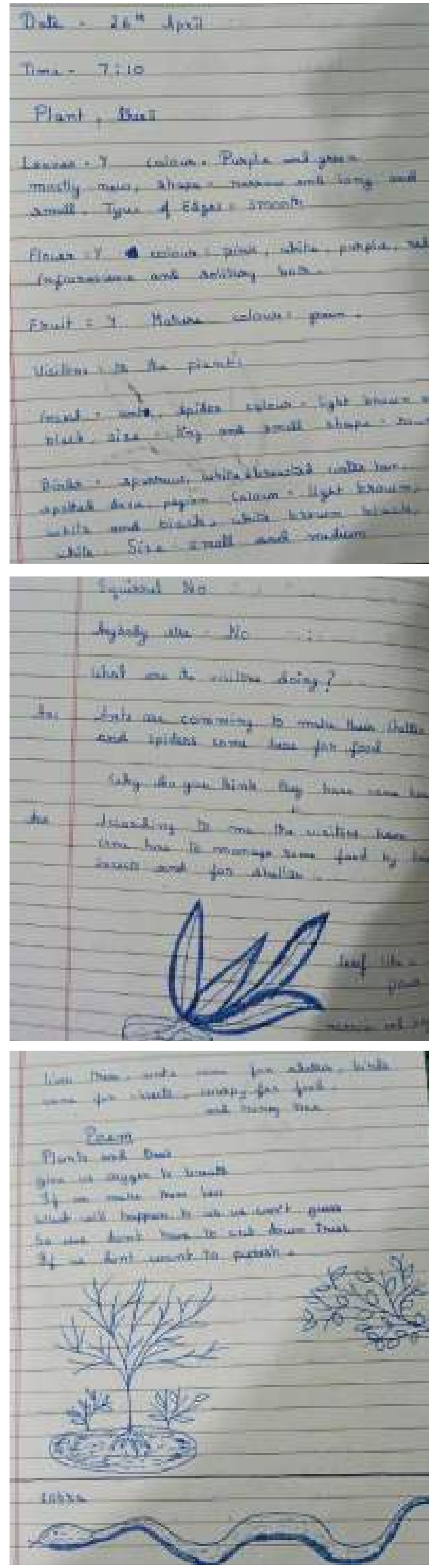


Fig. 1. Written observations, sketches, and a poem on plants by a student.
Credits: Radha Gopalan. License CC-BY-NC.

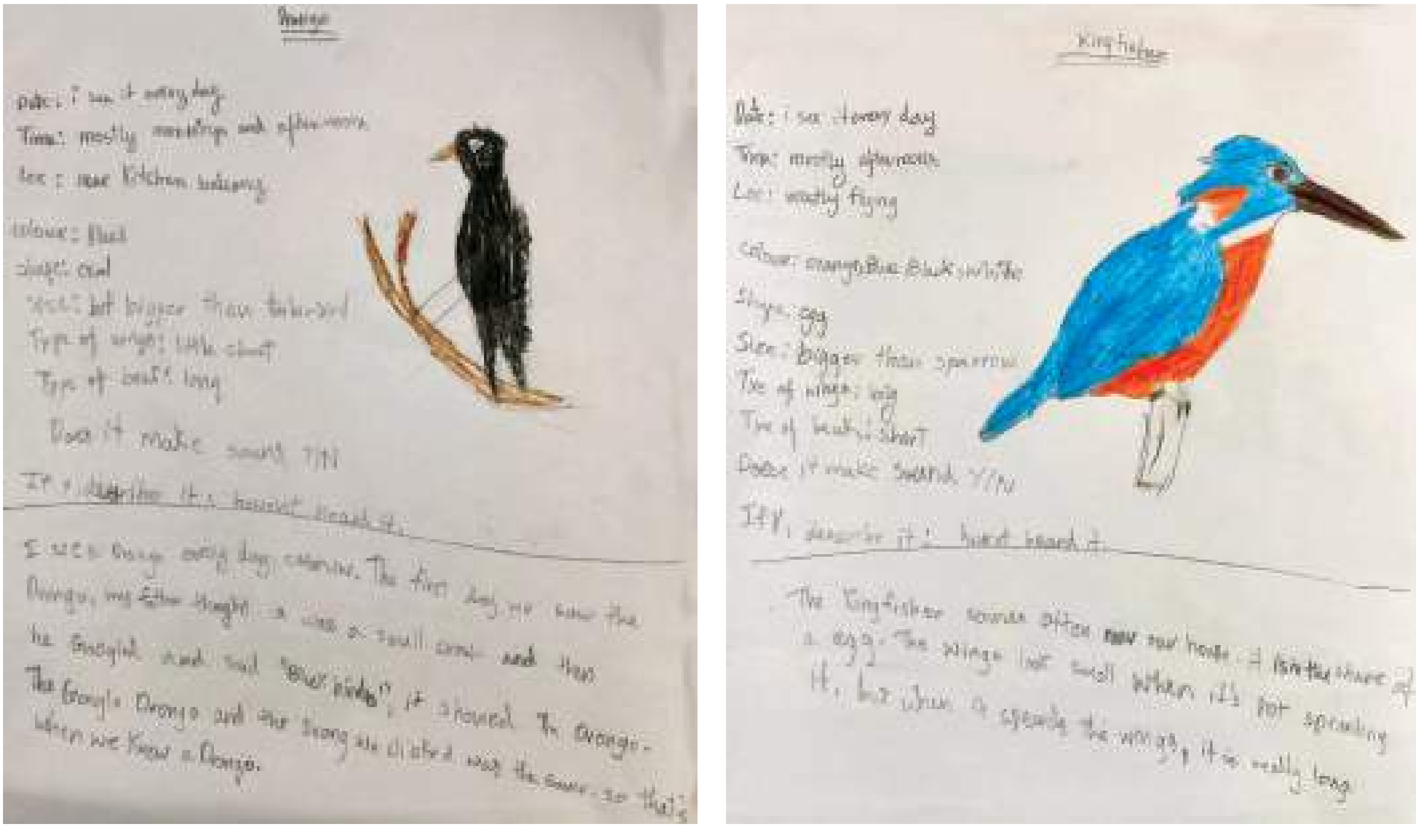


Fig. 2. Colourful sketches and descriptions of birds observed by a student.

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this small garden imagine what it must be like in a forest or in the sea! Is what we did over the last few days a part of Biology? Why can't we learn Biology in school by watching trees, birds, insects, and worms? Why is it important to use our senses and observe life around us?" As we tried to understand and discuss these questions as a group, one of the students suddenly burst into a bird call that he had been trying to master so that he could share it with us. It was a pretty good imitation of a bulbul.

The last two sessions brought the explorations indoors — again, students were encouraged to visit the same location multiple times. This led to a new set of questions and comments: *"should we let insects live in our homes? How do spiders weave webs? Why do some spiders weave webs and others just jump around? We shouldn't really clear the cobwebs in our house, right? Lizards are actually quite useful; they can keep your house clear of ants. How do ants communicate with each other when one ant sees food? They are so disciplined! Why are there no lizards in my house?"*

These questions led to a discussion about spiders, particularly the composition of web silk and its use in protecting eggs, capturing insects, and as a hunting tool. The sessions concluded with reflections about co-existence. Students remarked upon the fact that life was everywhere, inside and outside their homes — they only had to be attentive to sense it around them.

From questions to concepts

The questions raised by the students informed the various concepts and phenomena that were discussed during each of the online sessions. For example, questions related to the relationships between plants, insects, and birds in an ecosystem led to a discussion on food webs as well as of the phenomenon of camouflage and its role in predator-prey relationships. Questions related to pollination led to a discussion on its role in producing a large number of the foods that we eat, including several fruits, vegetables, and nuts. Questions on patterns and rhythms of biological events, such as fruiting and flowering of trees, led to an introductory discussion on phenology, the difference between bird calls and bird sounds, and between the appearance of males and females in many bird species. Using this approach, rather than pre-planning or structuring these discussions, allowed us to collectively weave together various related concepts.

Is structuring spontaneity really a paradox?

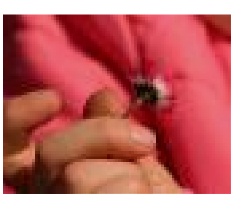
Often, learning sessions are structured around specific topics, like plants, insects, microorganisms, food chains and food webs etc. Once these topics are introduced in class, student activities are designed to focus on particular aspects in their environment. When students carry out sustained observations after learning about a topic, like pollination, their focus is limited to observations of pollination as an event. Consequently, their questions and learning experience are driven and limited by the teacher's imagination.

In contrast, choosing to selectively structure my online sessions based on student responses left room for students to make spontaneous observations and experience a sense of discovery.

Bringing in structure at specific points allowed for focused and systematic observation and deeper explorations – both of which are crucial in building awareness of the surrounding environment. This became apparent in the third and fourth sessions when there was a shift in the nature of students' observations. Going back several times to a location allowed them to sense changes in relationships, patterns, and rhythms. For instance, sustained observation of plants allowed students to become curious about relationships between insects and flowers, and patterns of insect movement between flowers at different times of the day. Understanding of pollination as one of the many relationships between plants and insects emerged from this curiosity and the inquiry that followed. Students raised questions like: *"Why do insects come to flowers? Why do they move from one flower to another on the same plant? Some insects keep going back and forth from a flower on one plant to a flower of another plant? Is it for food?"* These questions led to a discussion on pollination and climate change. Since students arrived at these concepts thorough their own experience rather than a textbook definition, this approach allowed for a more active and richer learning experience.

This made me wonder about the differences in the two learning experiences. A selectively structured session allows students to use their imagination and creativity to learn by observing, recording, reflecting, questioning, and inferring from their own observations. Learning from their own experience deepens and enriches students' understanding of concepts when they meet it in textbooks and other resources. It allows them to see relationships and connectedness in natural phenomena rather than perceive them as discrete, isolated topics in a textbook. This experience has led me to believe that structure and spontaneity can coexist for meaningful learning. Also, an educator can help create an immersive learning experience by acting as a facilitator.

Key takeaways



- Immersive learning experiences allow for spontaneity in learning, evoking wonder and curiosity.
- Structured learning experiences directed to specific topics and explorations can limit student imagination and learning.
- Open-ended sessions, selectively structured, bring focus and depth, building awareness and sensitivity to change.
- Minimal instructions, like those regarding ways to record, reflect upon, and draw inferences from observations, can enrich students' understanding of scientific ideas.
- Learning by observing and questioning allows students to weave together related scientific concepts experientially.
- Structure and spontaneity can coexist for meaningful learning. An educator acting as a facilitator can help create an immersive learning experience.

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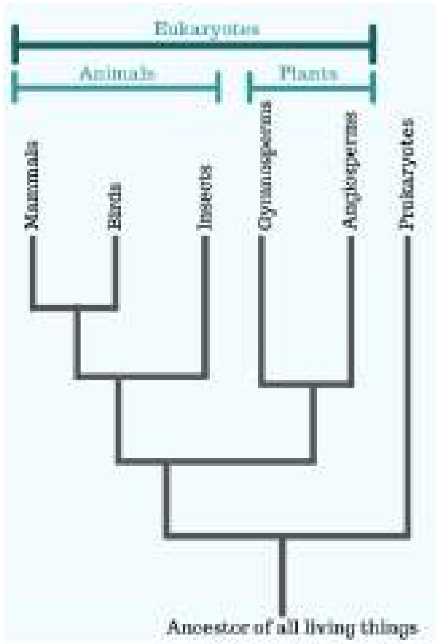
SNIPPETS

HOW ARE EVOLUTIONARY TREES BUILT?

Evolutionary trees are diagrams used to show evolutionary relationships between different species. They are based on estimates of how closely related current-day species are to each other.

How do we arrive at such estimates? Earlier, evolutionary relationships between species were determined on the basis of their external appearance (morphology). But this technique is not always reliable. Similarities in the physical appearance of two species can also arise from a process called **convergent evolution.** This is a process where distantly-related species evolve similar traits. For example, both birds and bats can fly, but we know that bats are mammals and their evolutionary history is different from that of birds. Modern methods look at how the genetic material of a present-day species is likely to have changed over time, given certain assumptions about the rate of mutation, past geological occurrences, etc. These methods can help determine the evolutionary history of present-day species far more reliably.

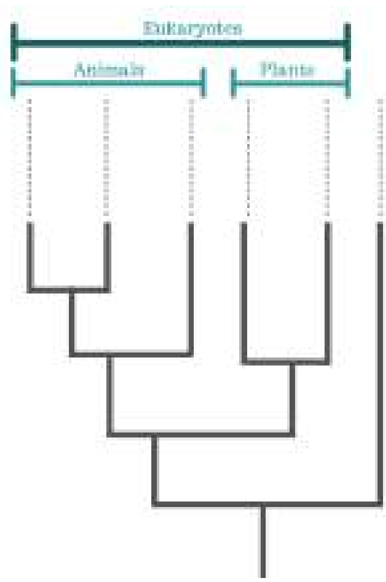


Build a tree activity

Background: You can build an evolutionary tree based on the assumption that organisms that are likely to share a common ancestor appear on branches splitting off at a node. For example, the tree on your top right shows how all living beings share a common ancestor, from which prokaryotes and eukaryotes split. Within eukaryotes, plants and animals share a common ancestor. Gymnosperms and angiosperms share a common plant-like ancestor; birds, insects and mammals share a common animal-like ancestor.

An activity for students: Share the background given above and the six taxa listed below with your students. Ask them to find out which categories these taxa belong to — animals, plants, prokaryotes, birds, or gymnosperms, etc. Can they use what they learn to fit these taxa into the empty tree on the right?

- *Gnetum ula*
- *Actias luna*
- *Bacillus thuringiensis*
- *Caryota urens*
- *Upupa epops*
- *Platanista gangetica*



Note for teachers: Students can be asked to bring pictures of these taxa, draw out the tree on chart paper, and paste the pictures in the correct spot. Don't forget to display the chart in your classroom!

Geetha Ramaswami heads SeasonWatch (www.seasonwatch.in), a citizen science project aimed at understanding seasonality through tree phenology, based at the Nature Conservation Foundation (NCF), Bangalore. She can be contacted at geetha@ncf-india.org.

HYDROPONIC FARMING

WITH TRIBAL STUDENTS OF ASHRAM SHALA

PRASHANT WAHULE

Children bring experience and observations from their real-world contexts into the classroom. Do these experiences and observations have any connections with classroom learning? Can children lead this process of science learning? What is the role of the teacher in this process?

In an oft-quoted approach to education, children are seen as empty pots that need to be filled, or shapeless clay that needs to be molded by the teacher. This approach is based on the assumption that scientific knowledge is absolute, and must be transmitted as is by the teacher to the students. It either ignores the knowledge that children bring into the classroom through their lived experiences or dismisses it as being scientifically incorrect. Consequently, children are rarely offered the opportunity to explore connections between these experiences and the concepts they are expected to learn in school. But what if we were to offer children this opportunity?

I explored this possibility with middle school children from Teesgaon Ashram Shala school, located 45 km from Aurangabad in Maharashtra. The children in this residential school come from remote areas and diverse tribal communities within a 90 km radius. Since their lives and culture are embedded in the forests where their homes are located, these children often have a deep relationship with the natural world. This contributes in significant ways to their knowledge about plants, seasonal cycles and rhythms, and traditionally diverse ways of growing food. Having seen glimpses of their food- and farming-related knowledge during brief monthly interactions with them, I designed an activity around a topic in their school curriculum — the role of soil in plant growth.

It is commonly believed that all seeds need soil to germinate and grow into plants. But the technique of hydroponics allows us to grow plants without soil (see **Box 1**). What if we were to introduce this method of farming to middle school children? How would it connect to their understanding of plant growth and their prior experiences with farming?

Box 1. What is Hydroponics?

Hydroponic farming is a technique of soil-less farming, in which water acts as a medium for germination and growth of seeds into plants in the same way as the soil usually does. Its key advantage is that it requires much less water and space than other farming methods. This means that farmers can use it to grow green fodder. Similarly, families with limited space in their homes can use this technique to grow enough organic vegetables for themselves. In addition, this technique can help protect plants against diseases caused by soil-borne pathogens.

Preparing the ground

I introduced this activity through a discussion with children from Grades VII & VIII. Their teachers were also invited to join the discussion.

I began the conversation with the question: *"Do you have a farm?"*

"Yes, we do!" declared the children.

I asked, *"Which animals help in farming?"*

The children listed cows, bulls, buffaloes, dogs, goats, hens, cats, etc.

I asked, *"Which of these produce milk and what do they eat?"*

"We get milk from cows, buffaloes, and goats. They eat green grass and dry fodder. The dry fodder is called kadba or kutti in Marathi."

I asked, *"Can we feed green grass to the animals throughout the year?"*

The children said, *"No...We get green grass only during the rainy and cold seasons. It is not possible to feed these animals grass all through the year. "*

I asked, *"What do you feed them during summer?"*

The answer was, *"We give them finely cut dry fodder mixed with a little salt."*

I asked, *"What will happen if we feed green grass to these animals, especially to the milk-producing animals?"* For a while, the whole class was silent. I thought I had asked this question rather too early.

After a while, the student sitting on the third bench excitedly said, *"Their milk yield will increase!"*

I said, *"Why? Could you explain this in a little more detail?"*

He said, *"If we give green grass to the milk-producing animals then they will produce more milk, and the milk will be slightly thicker also. I have seen this happen in my village!"* Some children laughed on hearing this. They may not have been aware of this connection, or this may have been the first time that the child had narrated his experience in such a manner.

I asked another question, *"What happens during summer when there is a dry spell and drought?"*

Children responded differently, *"Famine is a very bad situation... We have to walk huge distances to get drinking water! Animals do not get water to drink! Ponds dry up, farming stops, crops sown before summer are removed, animals do not get fodder, etc."*

I asked, *"What if green grass could be made available to farm animals even during summer?"*

Children started talking to each other. At this point, a voice was heard from the backbench, *"Milk-producing animals will become stronger, give more milk, and our income will also increase!"*

"Can we make green grass available to our animals for all the twelve months of the year?" I asked.

The children said, *"That does not seem possible at all! Crops need water. How can we find enough water in summer to grow fodder?"*

I asked, *"And can plants be grown without soil?"*

The children started laughing. But, after a few minutes, they started discussing this possibility with each other with puzzled expressions on their faces. Some of them looked at me expecting some clue. Then one girl said, *"No, we cannot grow anything without soil!"* Some of the other children nodded approvingly.

I said, *"Well, we can't grow anything without soil, but can we grow something only in water?"*

Again, the children said, *"No...!"*

I asked, *"When we sow a seed in the soil, it grows. Why? What does the soil contain to help seeds grow?"*

"The soil contains manure...there is water. There are micro-organisms in the soil. There are earthworms that live in the soil and eat wood and leaves found in the soil. Their excreta provide nutrients to the plants."

"But what if we could grow plants without soil? Would you like to try it out?"

While all the children said, *"Yes!"* in unison, they did not look as if they believed that this was possible.

Small beginnings

We started the activity with one kilogram of wheat grain (wheat was the only grain available in the school storeroom). I asked the children to soak these grains in a bowl of water to moisten them (see **Activity Sheet I**).

Noticing that the children removed the grains that floated up to the surface, I asked them, *"Why did you remove those grains?"*

After a brief discussion amongst themselves, one child said, *"These will not grow after sowing."*

I asked, *"Why?"*

The child said, *"Because they are spoiled."*

Another child said, *"They are infested with worms so we have removed them."*

We spread the soaked wheat grains on four trays (with breather holes), forming a 1-centimeter-thick layer. I explained that this was done to allow uniform exposure of all seeds to air, water, and sunlight. If the layers are thicker than this, the seeds at the bottom may spoil from microbial growth caused by lack

Fig. 1. Using trays and/or perforated bowls with breather holes allows the roots of seedlings space to grow.

Credits: Prashanth Wahule. License: CC-BY-NC.

of sunlight. Later, when the seeds had germinated, these holes would also allow the roots of the seedlings space to grow (see **Fig. 1**). I asked the children to look around for a cloth to cover the tray. A girl brought her old white scarf and covered them well.

I asked, *"Why do you think we have covered the trays with the cloth?"*

The children offered many reasons — to prevent air or sunlight from getting in, prevent water present in the wet wheat from evaporating, prevent rats from being able to get inside, or to maintain humidity (see **Box 2**).

I asked, *"Now that we have soaked these grains, what do you think is likely to happen to them?"*

"The grains will sprout by morning due to the humidity in the cloth-covered tray."

I asked, *"How do you know all this even though this is your first experience of hydroponic farming?"*

One of them said, *"We eat matki usal (sprouts). And it is kept in a wet cloth before making the usal."*

Box 2. Why do we cover grains with a cloth?

The response offered by the students is only partly correct. A cloth is used to cover the grains to allow air to move in and out. This air circulation would be blocked if the grains were covered with a plastic or carboard sheet. While covering trays with cloth may not prevent rats from getting to the grains, it may help retain humidity for longer.

The rest of the children agreed, and it seemed like half my job was done. The children prepared four more trays using wheat grains. I asked them to keep these trays in a dark place to prevent the grains from drying on exposure to sunlight.

The children then set up a similar activity using fenugreek and coriander seeds. But, this time, we spread and moistened the seeds in some perforated bowls (with the perforations acting like breather holes and improving aeration) lined with paper to prevent the seeds from falling through the perforations. Some of the children accepted the responsibility of watering the bowls twice a day, for 20 days, with a small spray pump. A pump is the cheapest way to disperse small air bubbles containing dissolved oxygen. Using these to water the growing plants helps ensure that their roots remain well-aerated.

Now was the time for patience and regular observation. Since the children stay at the Ashram Shala, they keenly watched these trays and bowls before, in between, and after the classes. They would report their activities and observations, on a daily basis, to their science teacher. Whenever it was possible, they would call and share their observations with me on phone. In 3-4 days, the seeds had sprouted, and the seedlings had started growing. Although I was unable to visit the school, the children kept me updated, and consulted me whenever they had any problems. On the ninth day, the children called to inform me that there was some fungal growth in the trays.

Rather than offering a solution, I asked the children, *"What could have led to this fungal growth?"*

One boy said, *"Sir, it has been very cloudy here for the last two days. Since it is quite hot inside the tray, the wheat must have become moldy."*

Some of the children were upset. They felt that all their hard work had gone in vain. But, a day later, one of their teachers sent me photos showing that the children had kept all the trays in the sun (see **Fig. 2**). This reduced fungal

Fig. 2. The children kept their trays of hydroponically grown wheat in the sun to reduce fungal growth.

Credits: Prashanth Wahule. License: CC-BY-NC.

growth. Neither I nor the other teachers of the school had asked them to do this; they did it on their own. I did not get an opportunity to follow up with the students to understand why they kept the trays in the sun. Where did this knowledge come from? Perhaps from having observed their parents working at home and in the fields.

When one of my colleagues, Sheetal, visited Ashram Shala, the children shared their experience with her, and expressed their wish to talk to me on the phone. Sheetal shared pictures of the trays and bowls showing the growth of the wheat, fenugreek, and coriander plants. On seeing the pictures, I felt that there were enough fenugreek leaves to prepare curry for two people. Since we had planted a limited quantity of wheat, its yield was too little for us to find out whether there would be any increase in the milk-producing capacity of dairy animals.

Through this activity, children developed an understanding of moisture, mold, planning of space, water administration, regularity of time, observation, etc. They were also able to get pesticide-free plants. This effort was not limited to just a feeling of 'children were able to practice farming'. It also provoked many questions that children shared with their teachers. For instance, *"what other crops can we grow with this method? How do we control fungal infections? Fertilizers are also necessary for plant growth. How do we give that to plants grown through hydroponic farming?"*

I tried to answer these questions through telephonic discussions with the teachers (see **Box 3**). During one of these discussions, one of the teachers expressed the belief that this activity would make it easier for the children to understand curricular concepts related to seeds, leaves, and roots. The students expressed the wish to share their experience with hydroponics farming in a science exhibition. Two students were chosen for this presentation. While slightly intimidated by the newness of this experience, the two students showed remarkable confidence — both in speaking about this group effort, and answering questions raised by the judges and other participants (see **Fig. 3**). I believe that this confidence, a rare sight, came from their keen sense of observation, interest, and the effort they had invested in this experience.

Fig. 3. Two of the tribal children presented their learning and experience of hydroponics at a science exhibition.

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Box 3. Nutrients in hydroponic farming:

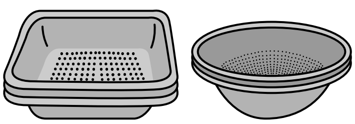
While unfiltered tap water is often sufficient for growing fodder, the filtered water used to grow crops for human cultivation may need to be re-mineralized with supplementary nutrient solutions (mainly nitrogen, phosphorous, and potassium). These nutrients can come from natural sources such as farm manure, chemical fertilizers, or synthetic nutrient solutions. To learn more about nutrient management in hydroponics, watch this: https://www.youtube.com/watch?v=6S6n3E3F4z0.

Parting thoughts

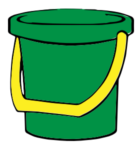
This brief experience of hydroponic farming in Ashram Shala has inspired me to teach and design activities that offer students the opportunity to express and apply their understanding from real-world experiences to the concepts and activities shared in the classroom. For example, hydroponic farming was helpful both as an example and as a medium for students to develop connections with concepts such as seed germination, the role of soil, roots, and water in plant growth, etc. It also offered them the opportunity to actively collaborate and learn from each other's food- and farming-related contexts and experiences.

ACTIVITY SHEET I: GROWING PLANTS WITHOUT SOIL

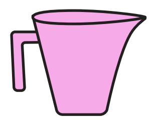
You will need:



Plastic trays or perforated plastic bowls (light-weight and portable ones, with many holes that help aerate seeds and allow space for its emerging roots to grow)

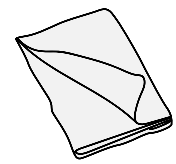


Bucket

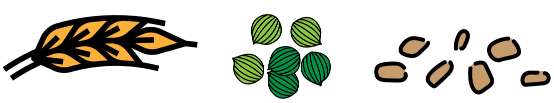


Mugs

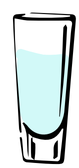
Plastic spray pump



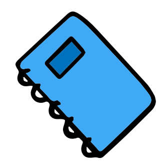
Piece of cloth (preferably cotton)



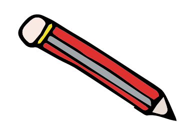
Some seeds of readily available grains, like wheat, coriander, fenugreek etc.



Water



Notebook



Pen/ pencil

What to do:

1. Soak seeds of grains in water for 2 h or overnight.
2. Spread the soaked seeds in a 1 cm-high layer on a tray/bowl.
3. Cover the tray/bowl with the cloth and place it in the shade.
4. Moisten the seeds with water from the spray pump, twice a day, for 20 days.
5. Observe changes in the seeds.
6. Record your observations in the table on the next page.

Discuss:

- How long does it take for the seeds to germinate?
- Are there differences in the appearance and growth rate of different seeds?
- How long does it take for roots to make an appearance?
- How long do these plants survive?
- How does the growth of hydroponically grown plants differ from those grown in soil?

i wonder... Rediscovering school science

Contributed by:
Prashant Wahule, who works as a research associate with Eklavya Foundation, Aurangabad (MH). His research interests lie in primary and middle school education. He is also deeply interested in agriculture, and sharing his experiences through articles and poems on social topics.

Azim Premji University

Days:	Wheat grains:	Coriander seeds:	Fenugreek seeds:
Day 1			
Day 2			
Day 3			
Day 4			
Day 5			
Day 6			
Day 7			
Day 8			
Day 9			
Day 10			
Day 11			
Day 12			
Day 13			
Day 14			
Day 15			
Day 16			
Day 17			
Day 18			
Day 19			
Day 20			

Key takeaways

- Children bring knowledge from their context and life experiences into the classroom.
- Designing activities that value children's prior understanding can help build stronger connections between their real-world experiences and the concepts they learn in the science classroom.
- Encouraging student-led inquiry, discussion, and collaborative work can help children to develop into confident learners.

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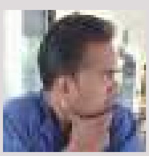
Note: Source of the image used in the background of the article title: Green fodder from wheat, grown by children using hydroponics. Credits: Prashanth Wahule. License: CC-BY-NC.



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WHY THE EARTH MATTERS: NAI TALEEM

"Why would it not rain? What will happen to the birds then?" One child answered indignantly, when I casually asked, *"What would happen if it doesn't rain this year?"* I was sitting with the children of Grade VI, from Ananda Niketan school in Sewagram, in front of a plot of land that they had tilled. They had sowed brinjal and okra on this plot, irrigated minimally, and weeded the area. Now, we were waiting for the rains. It was the last week of July, and we hadn't spotted any dark clouds. The summer had extended over more than two months, and even the leaves on the neem tree had started drying.

As per our practice in Nai Taleem, the children had begun engaging with the craft of agriculture. We had started infusing this ongoing activity with concepts of math, science, social studies, and languages. But that is not all that happens. The children develop a deeper connection with the land, birds, insects, and seasons. For them, the first rain isn't only about playing in the wet mud, although that is an essential aspect of their experience. They observe the soil quenching its thirst, the leaves flourishing into a deeper hue, the birds bathing in puddles, the farmer heaving a sigh of relief. These are lived experiences. Their knowledge of photosynthesis, pollination, transpiration, and anatomy isn't an efficient arrangement of air-tight boxes in the brain. It is an evolving method of experiencing a concept, not in isolation, but in the continuous network of beings and non-beings. It mingles with mathematics, engages with social studies, bonds with languages.

When the monsoons arrived a few days later, the children were overjoyed. They worked tirelessly on their plot to ensure that the weeds didn't overgrow the crop. It isn't easy to de-weed a thriving farm that is full of insects and ants, but they knew it was worth the effort. We didn't need to tell them why the earth mattered.

Credit: diego_torres from Pixabay (free for commercial use). URL: https://pixabay.com/photos/water-raindrops-raining-wet-liquid-815271/. License: CC0.

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COMMON SENSE IN THE SCIENCE CLASSROOM

KK MASHOOD & PUNYA MISHRA

Students can sometimes perceive scientific ideas to be in conflict with their common sense. How do we approach such conflicts in the classroom? Do we see these commonsense ideas as being wrong or, at best, misconceived? Alternatively, do we see them as resources and assets essential for the development of true understanding?

"...creative scientists are not only exceptionally gifted human beings — they are also human beings with a biological and social make up like all of us. The problem-solving strategies scientists have invented and the representational practices they have developed over the course of the history of science are very sophisticated and refined outgrowths of ordinary reasoning and representational practices."

— Nancy Nersessian.

Children understand and perceive the world around them intuitively, imaginatively, and socially — developing what we could call a commonsense understanding of the world (see **Fig. 1**). They know, for example, what is likely to happen if a small car stuck on the railway tracks were to collide with a massive fast-moving train. While the much smaller car will get crushed or be thrown violently away, the bigger, more massive train will fare much less damage. It is no surprise, therefore, that students tend to believe that the car will be hit by a greater force than the train.

Their teacher, however, tells them that as per Newton's third Law (every action has an **equal** and opposite reaction), **the forces acting on both, the car and the train, are the same!** This is in direct contradiction to what the students believe. One would expect, therefore, that a furore would erupt in class as students clamour to present **their** perspective. However, this does not happen in the classroom, barring rare exceptions. Even though it flies against their intuition (what they know by common sense to be true), the students are likely to listen to the teacher in silence. The more conscientious of them may even note down what the teacher has just said. But this doesn't mean that they have changed their minds. Their silence is not agreement or understanding of Newton's Third Law.

There is, in fact, ample empirical evidence to show that most students actually think that the force exerted on the car by the train is much greater than the other way round. They tend to hold on to this intuitive understanding even after extensive instruction. This is true not just in India, but across the world. When common sense meets direct instruction,

Fig. 1. Children understand and perceive the world around them intuitively, imaginatively, and socially — developing a commonsense understanding of the world.

Credits: The image to the left is by Ramesh Lanwani, through Wikimedia Commons (URL: https://commons.wikimedia.org/wiki/File:Girls_Playing.jpg; License: CC-BY). The image to the right is by foxypar4c, through Wikimedia Commons (URL: https://en.wikipedia.org/wiki/File:Street_Cricket,_Uttar_Pradesh,_India.jpg; License: CC-BY). Illustration and design by Punya Mishra. License CC-BY-NC.

common sense usually wins — though this may not always be obvious from students' responses in class.

The question for us, as educators, is — what do these commonsense understandings mean for learning in science? If they are important, how do we get students to voice them? How do we get students to use them to discuss, argue, and engage in building scientific knowledge? We believe that the answer to these questions lies, at least partly, in **how we have been thinking about** student ideas. Do we see them as a hindrance, a deficit, or as a resource for the development of true understanding?

The Dark age, Renaissance, and Enlightenment

"...I couldn't see how anyone could be educated by this self-propagating system in which people pass exams, and teach others to pass exams, but nobody knows anything."

— Richard Feynman.

In the car and train collision example, many students believe that the force exerted by the train is greater than that exerted by the car. Educators and education researchers conceive the nature and role of such student ideas in three main ways:

1. Student ideas as being either right or wrong — a binary assessment

Looking at student ideas as being either right or wrong is perhaps the oldest and the most traditional approach, widely prevalent even today. This approach is based on the assumption that scientific knowledge is absolute and not amenable to change or revision. A student's understanding either matches this or it does not. Any idea that does not match is wrong, and has to be replaced.

This perspective is often part of a larger narrative wherein the instructor is considered as the provider of knowledge. Thus, knowledge is transmitted from the instructor, and students are expected to receive it as is. Their understanding is evaluated in terms of its accuracy and fidelity to what the instructor has said. Student ideas, their nature, and their origins are irrelevant to the process of learning.

2. Student ideas as misconceptions — an impediment to expertise

Based on the work of people like Jean Piaget, this perspective acknowledges that most student ideas, even if incorrect, have a structure and robustness to them (see **Box 1**). In other

Box 1. Did you know?

Jean Piaget systematically studied how children learn, recognize, and identify patterns of thinking and knowledge building both through the process of cognitive development as well as their interactions with the world. Building on his insights, researchers in science education have identified a broad array of misconceptions or alternative conceptions that students have about various scientific topics.

words, rather than having arbitrary ideas, students develop their own coherent understanding of the world.

From this perspective, the goal of science education is to identify and confront incorrect ideas, and replace them with correct ones. Though a bit more progressive than the binary (right/wrong) approach, this approach still views student misconceptions as an impediment to expertise. Described more crassly, the message that is conveyed to students is that *"we will listen to your ideas, but you should get rid of them at the earliest, if they don't match ours."*

3. Student ideas as resources — essential to the development of expertise

If we consider the two perspectives described before as the dark ages and renaissance of science education, the next stage can be called the age of enlightenment. This approach recognizes and celebrates the creative, generative potential of student alternative conceptions. It recognizes that even scientists carry rich, complex and, sometimes, divergent understandings within themselves.[1] Thus, rather than being seen as hindrances, alternative conceptions are seen as nascent attempts to develop coherent frames to understand the world. This means that students are now placed in a continuum with scientists. Student ideas become the building blocks out of which more sophisticated knowledge structures get constructed, with the added benefit of elevating their sense of ownership and agency. This approach, where students construct their own knowledge by building on what they already know, is at the heart of constructivism. It changes the role of students, their status in relation to experts, and the metaphors underlying teaching and learning.

Is Newton's Third Law an assault on common sense? Not really!

When the collision of train and car is discussed in the context of Newton's third law, students usually imagine the scenario based on their experiences (see **Fig. 2**). What unfolds in their imagination is a huge, fast-moving object hitting a smaller object. In their

Fig. 2. When the collision of train and car is discussed in the context of Newton's third law, students usually imagine the scenario based on their experiences.

Credits: Image by Akshayapatra Foundation on Pixabay (URL: https://pixabay.com/photos/children-infant-girl-school-306607/; License: CC0). Illustration and design by Punya Mishra. License CC-BY-NC.

experience, this almost always results in the smaller object being flung away or getting crushed. It is from this mental simulation that students infer that the force on the car by the train is much higher than the other way round. While physics defines force as a quantity involving both acceleration and mass of the colliding bodies, students' inference about the force of collision relies solely on features of acceleration (implicitly incorporated in their common-sense reasoning). This perceived discontinuity can be mitigated if we deconstruct the collision example in such a way that commonsense notions are recognized and connected to the formal definition of force.[2] What are the implications of this approach on instruction?

Implications for instruction

Topics like Newton's Third Law are often taught by directly stating the definition of the law, then giving an illustrative example, and finally doing word problems based on the same. This is not only ineffective as far as learning is concerned, it also ignores how students understand the development of ideas in science, and denies them any agency in their own learning. Research offers these guidelines to a more effective approach:

(a) Give voice to student ideas:

Instead of thinking of students as passive recipients of knowledge delivered by teachers, invest in more proactive efforts to give voice to student ideas. The culture of silence prevalent in our classrooms should pave way for a culture of discourse and argumentation. How do we facilitate this in a traditional lecture-based classroom?

How to implement: Take 5-10 minutes after introducing a topic to pose multiple-choice questions to the whole class. The questions should be designed in such a way that the different choices incorporate students' ideas and alternative conceptions. In other words, the choices should act as scaffolding for students to voice their ideas in the class. Then, facilitate a discussion among students where they are encouraged to argue, and try to convince each other about the correctness of their choices.[3,4]

(b) Incorporate human elements in classroom discourses on science:

Rather than teaching only the core content of a subject, it is important to provide students with a clear picture of the **processes** that scientists use to think about and develop ideas. Seeing the human element in the enterprise of knowledge construction in science helps students understand that scientists are not always correct, and that they engage in constant refinement of their ideas. It also helps them appreciate how scientists often disagree greatly with each other. Seeing science as a human activity, laden with all the errors and biases that all humans have, helps students recognize their own role in its collective (or social) process of generating better understandings of the nature of the world.

How to implement: Present historical episodes that illustrate how great thinkers in the past harbored ideas similar to the conceptions students themselves have now.[5] For example, Aristotle, like many students, believed that rest was the natural state of objects, and motion implied a force.

Parting thoughts

Einstein once remarked that *"The whole of science is nothing more than a refinement of everyday thinking."* However, this image of science as a public and negotiated process of thinking, rooted in everyday experiences and imaginations, often gets obscured and lost in classroom contexts. With it are lost many prospects for authentic and engaged learning. This disconnect in the popular perception of science can be addressed by bridging the gap between student ideas and science concepts. We emphasize the need to adopt a pedagogical approach which helps students see that many formal concepts in science emanate from conceptions similar to the ideas they hold, and these are progressively refined by scientists in light of a larger body of evidence.

Key takeaways

- Children develop a 'commonsense' understanding of the world based on their everyday experiences. Sometimes this understanding appears to be in conflict with formal concepts taught in the science classroom.
- Students' ideas need not be treated as right or wrong, or as impediments to learning. They can be viewed as resources important to develop a more refined understanding of scientific concepts.
- Breaking down scientific principles to acknowledge commonsense notions and then connecting them to formal definitions could help bridge the gap between students' ideas and scientific concepts.
- Giving voice to students' ideas and bringing the 'human' element in a science classroom could help students identify science as a human activity, and recognize their own role in the process of knowledge construction in science.

Note: Background image credit: Gerd Altmann from Pixabay (free for commercial use). URL: https://pixabay.com/illustrations/rays-pattern-center-abstract-5562064/. Wordcloud created on Wordart.com. Illustration and design by Punya Mishra. License: CC-BY-NC.

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HUNTING & SEED SIZE:
A TALE OF EVOLUTION IN THE PRESENT

Some questions that frequently arise in discussions on evolution are — how fast do traits evolve in different organisms? Can we study evolution in the present? Do human actions impact evolution of traits in other organisms? A 2013 study by a group of scientists (Galetti et al.) offers some interesting insights.

Background: South America has rich forests with a vast diversity of fruit-eating birds. In some forests, hunting by humans has led to **defaunation** (the removal of larger-sized animals from the ecosystem). Galetti et al. were interested in investigating if this phenomenon could lead to the selection of a certain fruit size in populations of a bird–dispersed palm species *(Eutrepe edulis)* in forests.

Their hypothesis: Defaunation leads to the removal of large-sized birds, and smaller birds can disperse only small-sized seeds. The small-sized seeds will grow up to produce more small-seeded palms. Therefore, defaunated forests are likely to be dominated by small-seeded palms. In other words, smaller-sized seeds will be more frequently observed in the palms of defaunated forests. How did Galetti et al. test their hypothesis?

The study: The researchers sampled the seed sizes of *E. edulis* in 22 defaunated and intact forests in Brazil. They calculated the frequency of occurrence of different seed sizes. These were compared with the maximum size of a seed that could be eaten and dispersed by small frugivorous (fruit eating) birds (like thrushes) to see if the most seeds dispersed were by smaller or larger frugivorous birds. What did Galetti et al. observe?

The results:

- Smaller-sized seeds (smaller than the maximum size that could be eaten by small birds) were more frequently observed in *E. edulis* populations from defaunated forests.
- Both large- and small-sized seeds were frequently observed in *E. edulis* populations from non-defaunated forests.

Their inference: This led the researchers to conclude that the removal of large-sized frugivorous birds from these forest ecosystems has led to the dispersal, survival, and reproduction of only small–sized seeds in defaunated forests. In other words, small seed size has been selected for in *E. edulis* in defaunatated forests. This is an example of the rapid evolution of a plant trait in the present day.

Reference: Functional Extinction of Birds Drives Rapid Evolutionary Changes in Seed Size. Mauro Galetti, Roger Guevara, Marina C. Côrtes, Rodrigo Fadini, Sandro Von Matter, Abraão B. Leite, Fábio Labecca, Thiago Ribeiro, Carolina S. Carvalho, Rosane G. Collevatti, Mathias M. Pires, Paulo R. Guimarães Jr., Pedro H. Brancalion, Milton C. Ribeiro & Pedro Jordano. *Science*, 31 May 2013: Vol. 340, Issue 6136, pp. 1086-1090. URL: https://www.researchgate.net/publication/236977795_Functional_Extinction_of_Birds_Drives_Rapid_Evolutionary_Changes_in_Seed_Size.

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Write for us

If you are a practising **school science teacher, teacher educator**, or a researcher with an interest in the teaching & learning of school science — we would love to hear from you.

We welcome articles that offer:

- critical perspectives on science & science education,
- a deeper exploration of the foundational concepts & underlying principles in the school science curriculum,
- common student conceptions, ways of identifying, challenging or building on them.
- unit plans, activities, thought experiments, field guides & stories in science that engage the curiosity & imagination of your young learners, &
- examples of practice that encourage the learning of science in more meaningful & inquiry-based ways.

Topics of special interest:

Keeping our target audience in mind, we are particularly interested in submissions that are grounded in, connect, or emerge from these topics in the school science curriculum:

- **Physics:** Motion; Mass & weight; Density; Force & pressure; Momentum; Energy; Work; Power; Light; Sound; Heat; Electricity & circuits; Gravitation; Stars & the solar system; & Magnetism.
- **Chemistry:** Atomic structure; The periodic table; The particulate nature of matter; Structure & bonding; Chemical reactions; Acids, bases & salts; Air & water; Materials – metals & non-metals; & Fuels.
- **Biology:** Living & non-living; Cell structure & organisation; Biological molecules; Movement in & out of cells; Plant nutrition & transport; Human nutrition & transport in animals; Diseases & immunity; Respiration; Excretion; Coordination & response; Inheritance; Variation & selection; Organisms & their environment; & Human influences on ecosystems.

Themes for long articles (1500 words):

- **The Science Lab:** Tried-and-tested thought or practical experiments to teach a concept.
- **Annals of History:** The history of an important perspective, discovery, concept or invention.
- **In Here, Out There:** The 'life history' of one component within living systems (stomach) or in the extreme reaches of our physical world (black holes), preferably written in first-person.
- **Biography of a Scientist:** Their life & times through the prism of their contributions to science.
- **Teaching as if the Earth Matters:** Perspectives & teaching-learning approaches to sustainability, earth sciences, climate-sciences, & systems thinking.
- **The Science Educator at Work:** Perspectives & practices in teaching science written in first-person.
- **Big Ideas:** How do we introduce students to those powerful or illuminating ideas in science that help us make better sense of lots of confusing experiences & seemingly isolated facts?
- **I am a Scientist:** What does it mean to be a scientist, what inspired you to choose this path, what kind of questions excite you, & what you wish you'd learnt in school.
- **Hot off the Press:** Why recent headlines are of interest to students & teachers alike.
- **Book Review:** Why & how a book you've read could contribute to the teaching & learning of school science.

Themes for short pieces (200-600 words):

- **Myth or Fact:** Commonly held incorrect beliefs versus corresponding objective & verifiable observations.
- **10 Things You Didn't Know Anything About:** Ten interesting things about a concept, topic or theme that are not commonly written or heard about.
- **How Do We Know:** How do we know how far a star is from the Earth? Or, how many microbes live in the human body? Share your answers with us.
- **Snippets:** Do you know of a funny, fascinating, mysterious, or inspiring facet of science or scientists?
- **Posters:** On any topic or theme that teachers can use as a resource in the classroom.

Share your ideas with us:

1. Write a **brief outline (< 100 words)** that tells us:
   - What you want to write about
   - The key questions you hope to address
   - Why you think this will interest school science teachers
2. Include a **brief bio (< 50 words)** that tells us something about your:
   - Background in science and/or science education, &
   - Areas of interest in school science

Your outline & bio can be in English, Hindi or Kannada. **Send these to us at: iwonder@apu.edu.in. We accept submissions throughout the year.**

CONNECT WITH US

Read

We publish **two issues a year**, in **English, Hindi** & **Kannada.** Each issue has one theme section & many non-theme sections. Themes from our latest issues include: Big Questions, Evolution Revisited, & The Pandemic. Non-theme sections include: The Science Lab, Annals of History, The Science Educator at Work, Nature of Science/Why Science Matters, Life in your Backyard, I am a Scientist, Book Review, Biography, Research to Practice, 10 Things You Didn't Know About & Teaching as if the Earth Matters. Each issue also features short snippets, posters, activity sheets, and school-level field guides.

Ask & discuss

We invite authors & readers for **live, online discussions on the 2nd Wednesday of every month.** Some of the themes we have covered in the last year include:

- The Birth of Antibiotics with Rohini Karandikar, Subhojit Sen & Shiv Pandey
- Storytelling in Science with Rohini Chintha & Vinay Suram
- Distances in Astronomy with Anand Narayanan & Amol Kate
- Testing for COVID-19 with Yasmin Jayathirtha & Vijeta Raghuram
- Students as Teachers with Saurav Shome & Shiv Pandey
- The Pedagogy of Dirty Hands with Deborah Dutta & Radha Gopalan

Find us

To **receive notifications** about our latest issues & online discussions, please register at: https://bit.do/IWRegister. Or, **follow us on Facebook**: https://bit.ly/2UcVMaE.

To **watch recordings of our online discussions**, please check out our playlist here: https://www.youtube.com/playlist?list=PLVI4qkjTdM70DMzfEuffUoRgIycXZ589u.

To **subscribe to our mailing list** & receive free hard copies of every issue, mail your postal address to iwonder@apu.edu.in. Please note that the mailing of hard copies is restricted to India.

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Date: 1st June 2021

Signature of Publisher

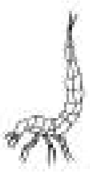
Know your pond mates!

Insects & Arthropods

Caddisfly larvae

Diving beetle

Dragonfly nymph



Diving beetle larvae

Insects & Arthropods

Mayfly nymph

Water boatman

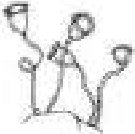
Water cricket

Whirlygig beetle

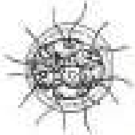
Water scorpion

Protozoans and Small Animals

Diatom

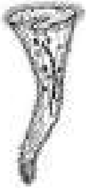


Vorticella

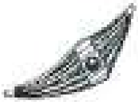


Pandorina

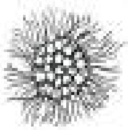
Euglena



Stentor

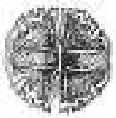


Closterium



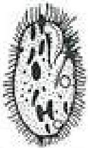
Synura

Colpidium

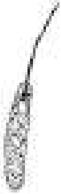


Micrasterius

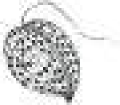
Protozoans and Small Animals



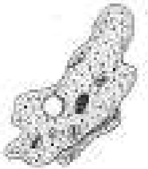
Stylonychia



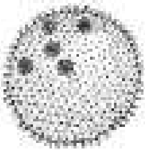
Peranema



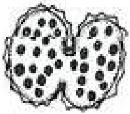
Phacus



Amoeba



Volvox



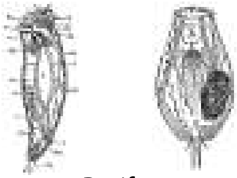
Cosmarium

Paramecium

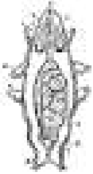
Spirogyra

Oscillatoria

Protozoans and Small Animals



Rotifers



Waterbear
(Tardigrade)

Nematode

Planarian

Cyclops

Water shrimp

Water flea
(Daphnia)

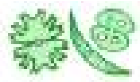
Algae and other Microorganisms

Volvox
(green)

Haematococcus
(red coloured)

Spirogyra
(green)

Dinoflagellate
(red, green,
some multicoloured)



Desmids
(green)

How many pond mates did you discover?

Credit details

I choose

Author: Rohini Chintha

Mittu ripped open his favourite pack of potato chips, turned on the television, and sat down to work on his school project. He browsed the internet for a while, penned down an idea, but dissatisfied, crumpled the paper, and began again.

Tatha grumbled.

Mittu took no notice and continued his work. In the next thirty minutes, he had eaten two packets of chips, crumpled 15 sheets of paper, and flipped three channels on the television set. Then he used Mom's mobile to call up a friend.

This time Tatha grumbled quite audibly. *"What is wrong, Mittu?"*

"What? I just want to find out what my friend has been doing!" said Mittu disconnecting the phone. *"I am trying to do my homework. Help me, don't grumble".* Mittu pleaded.

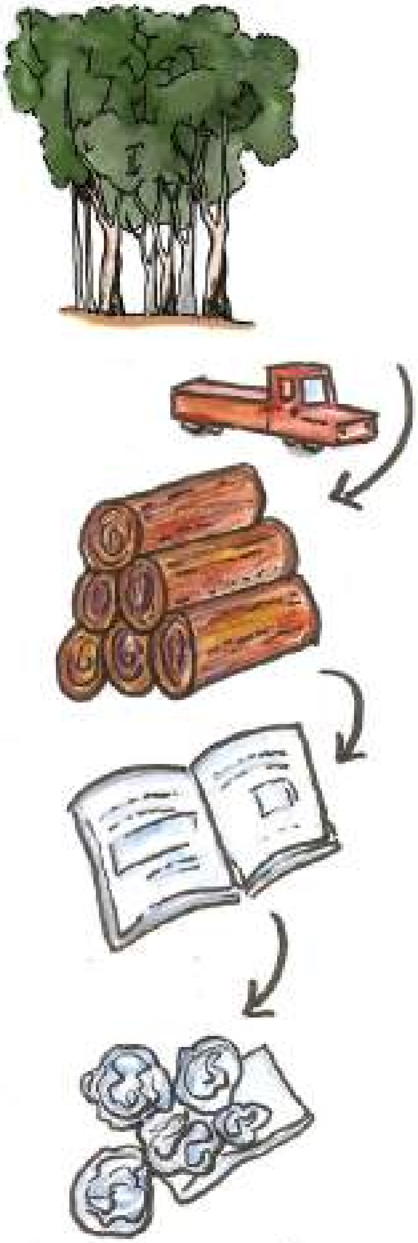
"Why do you have to crumple so many sheets and produce all this waste? Why do you need to turn on the television to work?" Tatha answered crisply. *"You are wasting your time, adding to global warming, and increasing your carbon footprint".*

Mittu opened his mouth to say something, but stopped abruptly.

"What global warming? What black footprints?" he said looking at the floor. *"It looks clean".*

"I said carbon footprint, not black footprint. The amount of carbon dioxide released into the atmosphere with each of your actions becomes your carbon footprint" clarified Tatha.

"I don't understand..." said Mittu perplexed.



"Well, let me explain. Look at those crumpled sheets of paper. Where do they come from?"

"From trees?" Mittu responded.

"Yes. One, cut trees," Tatha continued. *"Or deforestation. Less trees means more carbon dioxide in the atmosphere, because trees are not there to absorb it. Remember photosynthesis?"*

Mittu nodded.

Tatha went on *"Two, transport wood to factory in vehicles. Vehicles use fossil fuels like petrol and diesel for running. The burning of fossil fuels releases carbon dioxide into the atmosphere. Three, process wood into pulp using steam and electricity. Then, transport the pulp and finished paper products in vehicles. Again, carbon dioxide is released."*

"Stop, Tatha!" Mittu said abruptly. *"My head is reeling. What is the big deal with all the carbon dioxide? I send some out with every breath!"*

"Yes," said Tatha, *"we all do that to live. Inhale oxygen and exhale carbon dioxide. I am not talking about that. I am talking about the extra carbon dioxide that all of us may be adding to the atmosphere. It is this carbon dioxide that is harmful."*

"Okay..." said Mittu slowly. *"So making paper releases extra carbon dioxide into the atmosphere?"*

"Yes", Tatha said. *"And by wasting paper, you are releasing some more".*

"But how does my carbon footprint add to global warming?"

"Have you noticed the greenhouse in our garden?" Tatha asked.

"Yes! The glass room in our garden, right? Where mom grows her green leafy vegetables."

"Yes. But do you know why it has glass walls and a glass roof?"

"Why?"

"Because glass traps heat from the Sun, keeping the room warm."

"What has that got to do with global warming?" Mittu asked, perplexed.

"A greenhouse is like a miniature Earth." Tatha said. *"The Earth absorbs heat from the Sun."*

"I know...!" Mittu stopped Tatha halfway, *"Some of this heat keeps land and our oceans warm. Some of it is reflected back into the atmosphere."* Mittu looked expectantly at Tatha.

Tatha smiled, *"That's right! But the carbon dioxide and water vapour present in the Earth's upper atmosphere form a protective layer, like a blanket. They trap some of the reflected heat, keeping the Earth's surface warm. That is why we call both these gases* ***Green House Gases****."*

"But doesn't this trapped heat help support life on Earth?" asked Mittu.

"It does, Mittu." Tatha said. *"Just like the heat in the greenhouse helps the plants growing in it. But as the concentrations of carbon dioxide and water vapour in the atmosphere increase, more heat gets trapped, and temperatures across the globe increase. When the concentrations of these gases continue to increase beyond what we have known to be their normal limits, they make the Earth's surface very, very warm. So warm that Earth's climate starts changing".*

"Isn't this natural?" Mittu asked. After a pause, he added, *"Climate change is okay with me. I like warm weather."*

"Yes, Mittu, this atmospheric cycle is natural." Tatha smiled, *"But we are hastening this process with the scale of our activities. For example, the plants in the greenhouse like the warmth they are getting now. But imagine what would happen to them if the greenhouse kept getting hotter and hotter? The change in climate that we are seeing now is like that. It is different from the kind of warm we are used to. The average global temperature today is already 4-5 degrees Celsius higher than that during the last ice age. As the climate changes, summers will become unbearably hot. Hotter than in 2016."*

"The hottest year yet", Mittu said, thinking of the newspaper headlines he'd read.

"Yes, Mittu. Remember, nearly 20,000 people from across India died that year due to the heat? That's what will happen. Land will dry up. Water will become scarce" Tatha paused.

Mittu shuddered.

"That's not all, Mithu. Climate change is likely to increase the spread of infectious diseases like ZIKA and COVID-19. Animals that don't move to cooler places may go extinct. Those that move to cooler places are likely to come into contact with pests, predators, and competitors that they would not otherwise encounter."

"And?" Mittu asked.

"And how different species interact with each other will change. For example, it is not unusual for spruce trees to be attacked by bark beetles. But the changing climate has caused the tree's natural defenses to weaken, and helped the bark beetles to multiply and spread faster. The result — these beetles have wiped out nearly four million acres of spruce trees in Alaska!"

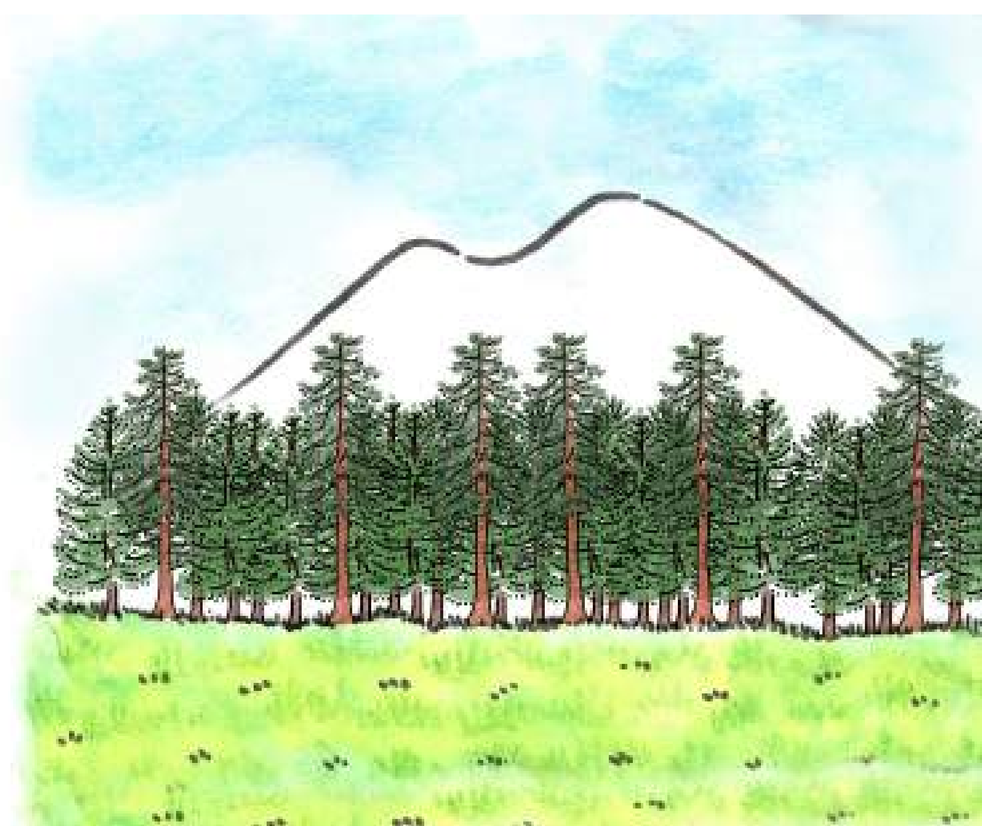
"Gosh! Less trees means more carbon dioxide in the atmosphere, isn't it?" Mittu asked.

Tatha nodded. *"This will cause a further increase in average global temperatures, and hasten climate change. See? This is a vicious cycle."*

"Can we not turn on the air conditioners if it gets that hot?" persisted Mittu.

"Oh, Mittu!" said Tatha sympathetically *"There will be nothing left to turn on. The rising temperatures will cause glaciers to melt rapidly. This quickened melting will will first cause overflow of fresh water sources, but as less of the glaciers remain, the fresh-water levels each year will keep reducing till they dry up. Millions of people depend upon this water. Their depletion will mean no drinking water for many people. And no electricity for those who depend on hydroelectric power from rivers."*

"If there is no water, we will not have a greenhouse or garden. And our own gardener will not have a job!" Mittu exclaimed.



"If things continue like this, we may also have to leave our homes. Even our country" Tatha said.

"But can't we get electricity by burning coal?"

"Yes, we can." Tatha said. *"But when we produce electricity by burning coal, more carbon dioxide is released into the atmosphere. If the global temperature increases by even just a couple of degrees more, the polar ice caps will melt. There will be no Arctic and Antarctic!"*

"What? But that would mean no polar bears. And, no penguins!" Mittu said in consternation, thinking of a wildlife programme he'd watched on television a couple of days ago.

"No polar bears, no penguins, no us!" Tatha said.

"No us?" Mittu shuddered.

"No us". Tatha said sadly. He let Mittu grasp this idea before continuing, *"Because all the ice that melts will enter our oceans. Sea levels will rise and flood coastal areas, just like a bucket overflows when you leave a tap open. The only difference is that we live in those spilled over areas. Floods destroy plants, animals, property, fields and also people".*

"Okay," said Mittu bravely, *"I will not waste paper anymore. Will this stop climate change?"*

"Paper wastage and fossil fuel usage for transport of paper and paper products are just a few examples of activities that hasten climate change, Mittu" Tatha said. *"Large-scale activities like generation of electricity, industrial and vehicular pollution, and deforestation for agriculture contribute much more to this change."*

"How can we reduce our carbon footprints, Tatha?" Mittu asked. *"What can I do to make a difference?"*

"Simple things. For example, cut down on television time, turn off the air conditioner for a day, browse books instead of the internet, go off your phone for a day, carpool, use LED lamps, recycle paper and organic waste…" Tatha paused before he added, *"Think of all that you can do, Mittu. Being more responsible starts with our personal choices".*

Mittu sensed that the ball was in his court. *"Then, I choose!"* he said enthusiastically *"I choose to save the environment. I choose to save the Earth. I choose to save us".*

"How?" Tatha questioned.

"I will bicycle to school, Tatha" Mittu said. *"And I'll go gadget free for a couple of days a week. No television on one day, no mobile on the other!"*

"That's a good place to start, Mitthu." Tatha looked at Mittu unsmilingly *"But do you know what you will leave then?"* he asked.

"What?" Mittu asked, looking terrified.

"A positive effect on our environment. Your ***carbon handprint****!"* Tatha smiled.

Mittu beamed. He immediately turned off the television, picked up the crumpled sheets of paper, and smoothened out the creases with his hands. He kept some aside for future use, and jotted down ideas on one of them. After he'd finished his project, he sat down beside Tatha, and happily browsed through a book on penguins.

About the Author

Rohini Chintha is an Assistant Professor (C) at the Department of Genetics and Biotechnology, University College for Women, Hyderabad. She is passionate about writing for children, and believes that 'A Happy Childhood builds a Happy Society'. About 85 of her stories for children have been published in various magazines. To view her work, check out her website: www.popscicles.com.

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i wonder... Rediscovering school science

Azim Premji University

"...We have such a brief opportunity to pass on to our children our love for this Earth, and to tell our stories. These are the moments when the world is made whole..."

– Richard Louv

Catch the next issue of **i wonder...** to read more perspectives on **Teaching as if the Earth Matters.**

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