PAYING ATTENTION TO WHAT CHILDREN DO: EXPLORATIONS OF SOUND

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What is a child's relationship with the world of phenomena? How do children engage with and explore 'stuff' in their natural and physical environment? Can this understanding inform the teaching and learning of science at school?

As humans, we are more likely to notice the things that we expect to see. More specifically, as teachers and educators, our observations of children tend to be influenced by the images and theories that we hold about them and their capacities. My experiences with teaching and learning science suggest that paying attention to how children explore phenomena, like sound, in their environment can often make us more aware of these images and bring them sharply into focus.

Exploring sound at school

My first opportunity to engage with science education came while working as a middle school science teacher in Vidya Vanam, located in Anaikatti in the Nilgiri foothills, near Coimbatore (see **Box 1**). This english medium school for children from the Irula indigenous or Adivasi community (most of whom are first generation learners) has an atmosphere of free and open dialogue between children and teachers. It is here that I first witnessed the remarkable abilities that 8- to 12-year-olds can bring to their explorations of physical phenomena.

I started a discussion on the topic of sound by inviting my students to notice the different sounds around them, at school and at home, and map these **soundscapes** on paper (see **Box 2**). The soundscapes that the children produced were quite perceptive. For example, a student who was deeply interested in birds, drew the various birds that he could see and hear

Box 1. My approach to teaching and learning science:

As a freshly minted physics PhD, my approach to science education was to bridge the gap between how science is practiced in research and how it is taught and learnt at school (and university). Therefore, I found it relevant to enter the world of teaching and learning of science the way one starts with new areas of research. This meant starting from scratch, asking questions, seeking help from peers, referring to existing literature, stumbling or fumbling at times, modifying one's questions at times, learning new things along the way, and keeping at it.

I also found that the relatively democratic nature of the teaching-learning culture I experienced in a US university (as a graduate student and while teaching undergraduate students) offered some lessons for the Indian context. This included practices like asking questions and asking for help — both of which are related to the idea that not knowing something is not a stigma; making progress in learning is what matters.

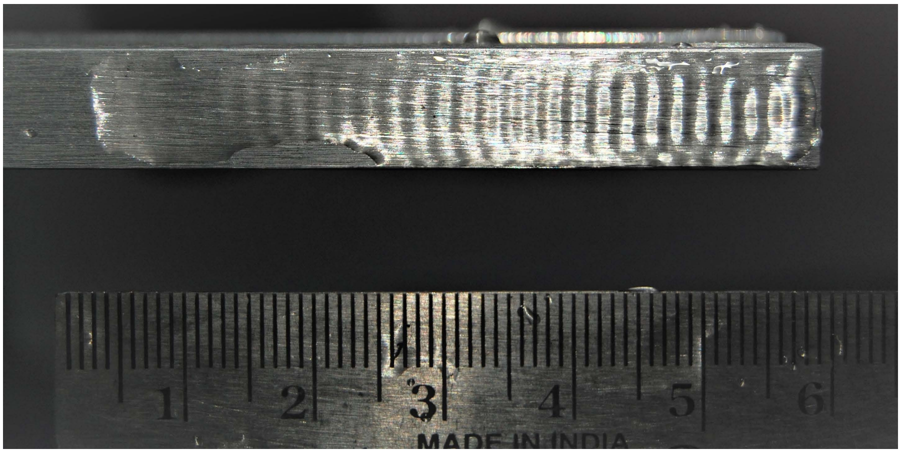

Fig. 1. Standing waves forming on water on the surface of a vibrating tuning fork.
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around his home as well as the trees that he would typically spot them on. Another student noticed 'the sound that a tube light makes in the quiet of the night'. I used this exercise to draw their attention to the fact that sound is produced when something vibrates. For example, we can see guitar strings vibrate, feel a *tabla* vibrate after we strike it, or sense the vibrations of our sound box or muscles by feeling our throats while we speak. Once we were able to reason that all sounds are related to vibrations, I proposed that the sounds we hear are nothing but vibrations that travel to our ears from the things that vibrate.

This led to the question of how these traveling vibrations reach our ears. To help them imagine sound traveling as a wave through air, I had planned a common demonstration — to hold a vibrating tuning fork to the surface of water to create ripples in it. This pedagogic device can help students appreciate how vibrations of the fork can create waves on the water surface that travel away from the fork. This can then be connected with the idea that sound (more concretely, the sound of the tuning fork) is itself a wave that travels through air. But before I could start the demonstration, the children noticed how the slanting rays of the bright morning sun were reflected from the surface of water in the bucket and projected on the ceiling. We paused for some time to marvel at how even the small drops of water dripping from our fingers created dramatic patterns of waves on the water surface and ceiling. This allowed students time to notice these waves and enjoy their aesthetic aspects.

Box 2. Mapping a soundscape:

In the school context, we could think of mapping a soundscape as an observational exercise or activity in which students take time to patiently listen to the many different sounds in their surroundings at different times of the day.[1] They could also be encouraged to walk around the place a few times. They could record their observations on a piece of paper or on the blackboard, while also spatially depicting their approximate location (relative to themselves), possible source, loudness, duration, pitch, etc.

I followed this with the planned demonstration. While we discussed our observations, I sensed that something else had caught the fancy of one of my students. He seemed to want to explore how the water in the bucket splashed around due to the vibrating tuning fork. After observing this for some time, he called me, *"Anna, see this!"*. I went up to where he was stooped over, standing in a small puddle. He made the tuning fork vibrate as he had seen me do for the demonstration, but poured water on it instead of touching it to the water surface as I had done. I watched, dumbstruck at the pattern of standing waves forming on the water on the vibrating tuning fork (see **Fig. 1**).[2] He said something along the lines of: *"Are these waves too?"* Since I had not anticipated this, it took me some time to recognise these as gravity-capillary waves, in which both gravity and surface tension play a role. I appreciated his exciting 'discovery' and helped him share it with the other students.

A few days later, I wondered out loud if we could somehow see sound. We had been talking about how sound waves may not be visible because of air being transparent. After some tentative responses, one of my students had a Eureka moment and shouted out "Powder! Powder!" We sprinkled some talcum powder on an upturned steel plate and touched a vibrating tuning fork to its sides (see **Fig. 2**). This gave rise to a pattern of mounds of powder that led another student to remark with

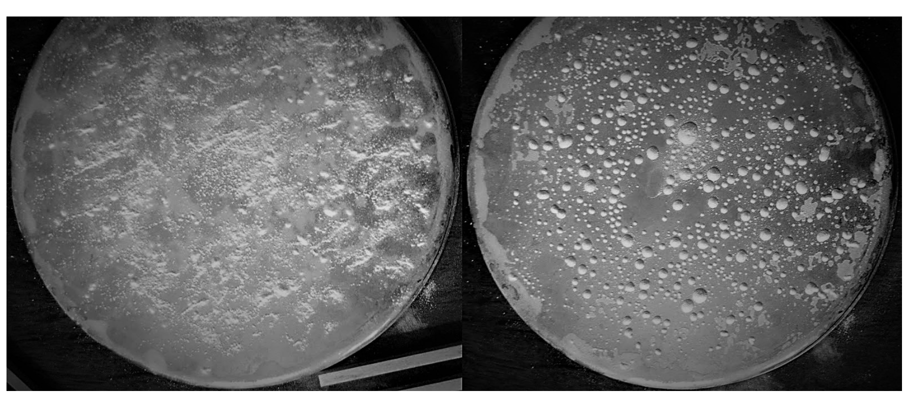

Fig. 2. Mounds of powder making a pattern on a steel plate after touching a tuning fork to it.
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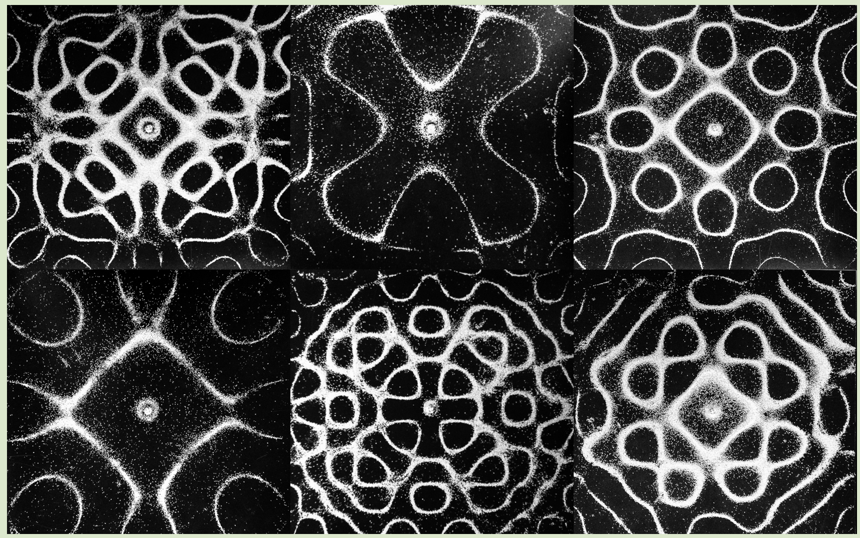
delight: *"It looks like a butterfly!".* I was reminded of Chladni figures (see **Box 3**).

In a few days, a student extended the idea of visualising vibrations by sprinkling some powder on the flat surface of a vibrating tuning fork. The powder collected in a straight line of mounds, and seemed to circulate within each mound (see **Fig. 3**). A few years after this incident, I found the same phenomenon mentioned in Michael Faraday's book 'Experimental Researches in Chemistry and Physics' from 1859. Faraday describes it as, *"If a tuning-fork be vibrated, then held horizontally with the broad surface of one leg uppermost, and a little lycopodium be sprinkled upon it, the collection of the powder in a cloud along the middle, and the formation of the involving heaps also in a line along the middle of the vibrating steel bar, may be beautifully observed".* This phenomenon is related to Chladni figures as well as to the flow of induced air currents near the surface of a vibrating tuning fork. It also happens to be an active field of research within acoustic streaming and interfacial science. Going further, the student also found out that if we tilt the tuning fork slightly downwards, the mounds of powder start moving up the incline, against gravity.[4] Since I have not found any mention of this phenomenon in scientific literature yet, it could be a novel observation.

Box 3. What are Chladni figures?

Named after the 18th century German scientist Ernst Chladni, these figures are patterns formed by a powder-like or grainy substance on the surface of a vibrating plate, membrane or sheet. Standing waves are formed on vibrating parts of the plate, and the powder collects in regions where the plate does not vibrate (called nodes or nodal regions).

The vibration frequency at which this occurs is one of the resonant or natural frequencies of the plate, which depends on its shape (say, circular, rectangular, etc.), its thickness, and the material with which it is made.[3]



Chladni patterns formed by powder or sand on a plate vibrating at different resonant frequencies.

Credits: Chris Smith. URL: https://www.flickr.com/photos/cjsmithphotography/8800645088/.
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Exploring sound at home too

Do such explorations of sound occur only during activities planned by an adult? In response to this question, I would also like to share some instances of spontaneous or unplanned explorations of sound by my daughter that I was able to observe quite easily.

On one occasion, my daughter (who was a little over three years old at the time) was loudly humming a tune while holding a balloon. Suddenly, she thrust the balloon into my hand, brought her face close to it, and with much excitement started humming again. I could feel the balloon in my hands vibrate. To test the possibility that this vibration was caused by an air draft, I asked her to hold a sheet of paper between her mouth and the balloon. I could still feel the balloon vibrate, which meant that it was caused by the sound of her humming. Later that year, I used this experience to design an activity for high school students in a blended learning module for the Connected Learning Initiative (CLIx) at the Tata Institute of Social Science (TISS), Mumbai. This activity can be used to encourage students to explore sound and its propagation using a balloon (see **Activity Sheet: Vibrating Balloon**).[5]

My daughter shared another such observation more recently, when she was playing with a drum made of a rubber balloon stretched over a cup.

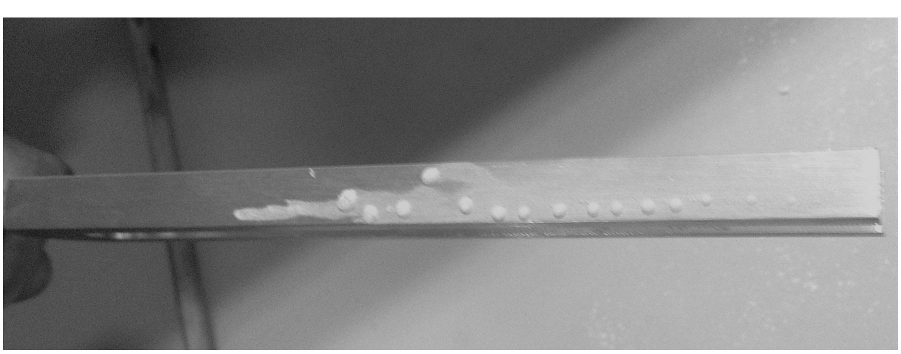

Fig. 3. Mounds of powder forming in a line on a vibrating tuning fork.

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Box 4. What do we mean by protoscience?

The term 'protoscience' is used to refer to science in its formative stages. This involved explorations of natural phenomena by processes that did not begin as but gradually evolved into the formal processes that we associate with science today. These included making careful observations of phenomena, performing experiments, making measurements, or using mathematics to describe things. Why is this relevant in science education? Many of the naive conceptions that children and adults have about phenomena were at some time, in the history of science, widely accepted explanations. Recognising such connections between children's efforts and the work and ideas of early thinkers from the history of science could help bring a flavour of the process of science into the act of learning science in the classroom.

She showed me how the drum made a resonating sound when she blew air over the rubber diaphragm in a certain way.[6] This may have been because the frequency of the diaphragm's oscillations matched one of the resonant or natural frequencies of the drum cavity/cup.

Paying close attention to what children do

Having witnessed these instances of children seeming to stumble upon non-trivial phenomena, I started observing children's explorations of phenomena more carefully. I also wondered if I may have been underestimating children's capabilities and overlooking other such explorations that may have happened right before me. This is not to suggest that we, as teachers, romanticise children and their abilities, but merely to emphasize the need to recognise them for what they are. While children may not be able to grasp mathematically abstract and complex theoretical aspects of phenomena, exploring and noticing finer details of the same certainly seems to come easily to them.

What we teach as science at school is the result of a social process — people being curious about physical and natural phenomena; exploring them in creative ways; borrowing, exchanging and debating ideas with others; thinking and rethinking hypotheses, concepts, and theories in the light of new experiments. As teachers and educators, acknowledging the seeds of a similar process within children too may provide us with opportunities to help students deepen their engagement with phenomena and concepts. We may be able to leverage children's capabilities in creatively exploring and interpreting physical phenomena to link the **learning of science** to the **doing of a kind of protoscience** (see **Box 4**). This may allow students to develop a personal connection with science and make its process their own. Just as one appreciates a good poem, one may also feel an affective connection with phenomena that one has experienced aesthetically. Besides, come to think of it, wouldn't fascination with phenomena be a good enough reason to want to keep studying science?

In addition, it may offer an approach to work on two important recommendations of the National Curricular Framework (2005) Focus Group on the Teaching of Science. One of these recommendations is to 'stimulate creativity and inventiveness in science'. The other is to help children build familiarity with phenomena till the middle school level (and to work on abstract concepts and theories related to these phenomena in high school). Recognising how different children engage with phenomena may help us to think of many possible ways to reach these goals. We may also discover that children are already quite good at some of these things, and all we need to do is to facilitate such processes further to 'make learning visible' (see **Box 5**).

Lastly, being aware of and open to such possibilities when children work with the physical-natural world may have value in setting the foundations to accord dignity to students and to their efforts within school and outside it. It may provide us with the opportunity to introduce science as a creative and social endeavour, and invite children to participate in this endeavour, to whatever extent possible. It may also allow us to move towards a more democratic discourse around science in the classroom. Thus, paying close attention to these aspects might help us design better teaching and learning experiences around school science (see **Box 6**).

Box 5. What do we mean by 'making learning visible'?

Drawing from the educational practices and perspectives from the municipal preschools of Reggio Emilia in northern Italy, this involves documenting and displaying children's work to 'make learning visible' for them, their parents, and teachers. This documentation is used to anchor a collaborative dialogic process of pedagogical reflection for improving teaching-learning, for building on children's work, and for facilitating continuous teacher professional development in small groups at school. It is accompanied by some other philosophical positions and pedagogical practices that may be suitable to adapt for the teaching-learning of science at the middle school level — the 'hundred languages of children', 'the pedagogy of listening', as well as the practice of observing children.[7]

Box 6. Did you know?

Finland has adopted a phenomenon-based learning approach to ensure that learning does not remain at a hypothetical level; students are able to apply it to their real-world contexts too. This approach also helps students appreciate internal consistency in any domain of knowledge and interconnections between different domains that are otherwise demarcated into separate subjects at school.

Parting thoughts

In an article written in 2005, Prof. Yash Pal had called for working towards a child-inspired education system.[8] Perhaps this excerpt from his foreword to the National Curricular Framework (2005) is a good place to conclude: *"Since children usually perceive and observe more than grown-ups, their potential role as knowledge creators needs to be appreciated. From personal experience I can say with assurance that a lot of my limited understanding is due to my interaction with children."*

Key takeaways

- Children notice minute details and nuances of physical-natural phenomena; they sometimes stumble upon novel phenomena that teachers and educators may not have seen before.
- Paying close attention to what children do (and say) while exploring phenomena reveal interesting aspects of their engagement with the world around them and of how they make sense of things.
- Being cognizant of children's facility in exploring phenomena and documenting their work could help us think of creative ways of teaching science at the middle school level.
- Such efforts could also help to personalise a subject like physics that many students find daunting.

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Notes:

1. An article describing some of these experiences of witnessing children exploring phenomena has previously appeared in Sandarbh in Nov-Dec 2014. URL: https://www.eklavya.in/pdfs/Sandarbh/Sandarbh_95/23-36_Science_With_Children.pdf.
2. Source of the image used in the background of the article title: Child playing drums. Credits: Junuka Deshpande. License: CC-BY-NC.

Additional references:

1. Read more about how to design an activity to encourage children to create soundscapes here: https://www.nationalgeographic.org/activity/soundscape/.
2. Watch a short video clip of standing waves forming on water on the surface of a vibrating tuning fork here: https://www.youtube.com/watch?v=0UbH9nhjhR8.
3. Read more about Chladni figures in this post from the Scientific American: https://blogs.scientificamerican.com/but-seriously/chladni-figures-amazing-resonance-experiment/.
4. Watch a short video of the mounds of powder moving up the incline against gravity here: https://www.youtube.com/watch?v=nOLmc0pUesY.
5. Find an activity to explore sound and its propagation using a balloon here: https://clixplatform.tiss.edu/sound/course/activity_player/59b7e5272c4796015b350c69/59b7e5312c4796015b350d0c/. You could browse the entire module for other ways of teaching concepts related to sound. Links to download a student workbook and a teacher handbook can also be found on this online platform.
6. Watch a short video clip of how blowing air on the drum produces a resonating sound here: https://www.youtube.com/watch?v=cWd3SpSubUc.
7. Read more about the philosophical approach, pedagogical ideas, and educational practices from Reggio Emilia here: The Hundred Languages of Children: the Reggio Emilia experience in transformation. Carolyn Edwards, Lella Gandini and George Forman (editors), Praeger, Santa Barbara, California, 2012.
8. Read the complete article by Prof. Yash Pal here: For a child-inspired education system, The Hindu, September 6, 2005. URL: https://www.thehindu.com/todays-paper/tp-national/for-a-child-inspired-education-system/article27462698.ece.

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ACTIVITY SHEET : VIBRATING BALLOON

Hold a balloon in front of your friend's face and ask your friend to shout "ouuu" in a loud voice.

Q. What happens?

Q. Why do you think it happens?

Q. Is it due to the air that comes from your friend's mouth?

Hold a paper or a notebook between the balloon and your friend's mouth to block the air. Now ask your friend to shout again.

Q. Do you still feel the vibrations?

Take two steps away from your friend. Ask them to shout.

Q. Does the balloon still vibrate?

Q. Do you want to do something else with the balloon that is related to this activity/to sound?

Note: This activity was first published here: https://clixplatform.tiss.edu/sound/course/activity_player/59b7e5272c4796015b350c69/59b7e5312c4796015b350d0c/. This copy is shared here with the permission of the author.

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ACTIVITY SHEET: VIBRATING BALLOON

TEACHER'S GUIDE

1. This activity was originally designed for high school students.
2. The time requirement for the activity is one block period.
3. Since this activity involves shouting at a high pitch, it might be advisable to perform it outdoors or in a place where other classes are not disturbed.
4. The various discussions following the activity would need to be guided to some extent. Hence, it may help to have a co-facilitator.
5. Pair up the students, and give a balloon and a sheet of paper to each pair.
6. Preferably, give out the instructions and questions one at a time; moving on as and when they finish a given task. These could be written on a blackboard or passed on as chits of paper.
7. Encourage each pair of students to record their responses to the questions on a sheet of paper. Clarify that this exercise is not about getting 'the right answer'; rather it is an invitation to think, discuss, and record their ideas.
8. After each group of two has finished the entire activity, many such groups could be merged into a larger group, so that there are around 6 to 8 groups in all. Each such large group could be given 15 minutes for discussion. They could read out their responses as well as any observations and ideas that they may not have written down. Encourage students to ask each other to clarify the meaning of their responses. At the end of 15 minutes, invite the larger groups to share a summary of their discussion.
9. Record interesting or unique points and questions from each group presentation on the blackboard. These could be taken up for further discussion with the whole class.
10. Some groups may have performed variations of the activity (you would have to be on the lookout during the discussions) or might have ideas for an experiment to extend some ideas. Invite them to share these too at this point.
11. Invite a few students to emphasize the main points that emerged from the activity and the discussions. It is possible that the answers to some questions or extensions of experiments may not be obvious at this point. These can be taken up later to connect this activity with other concepts related to sound, or/and as project work.

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