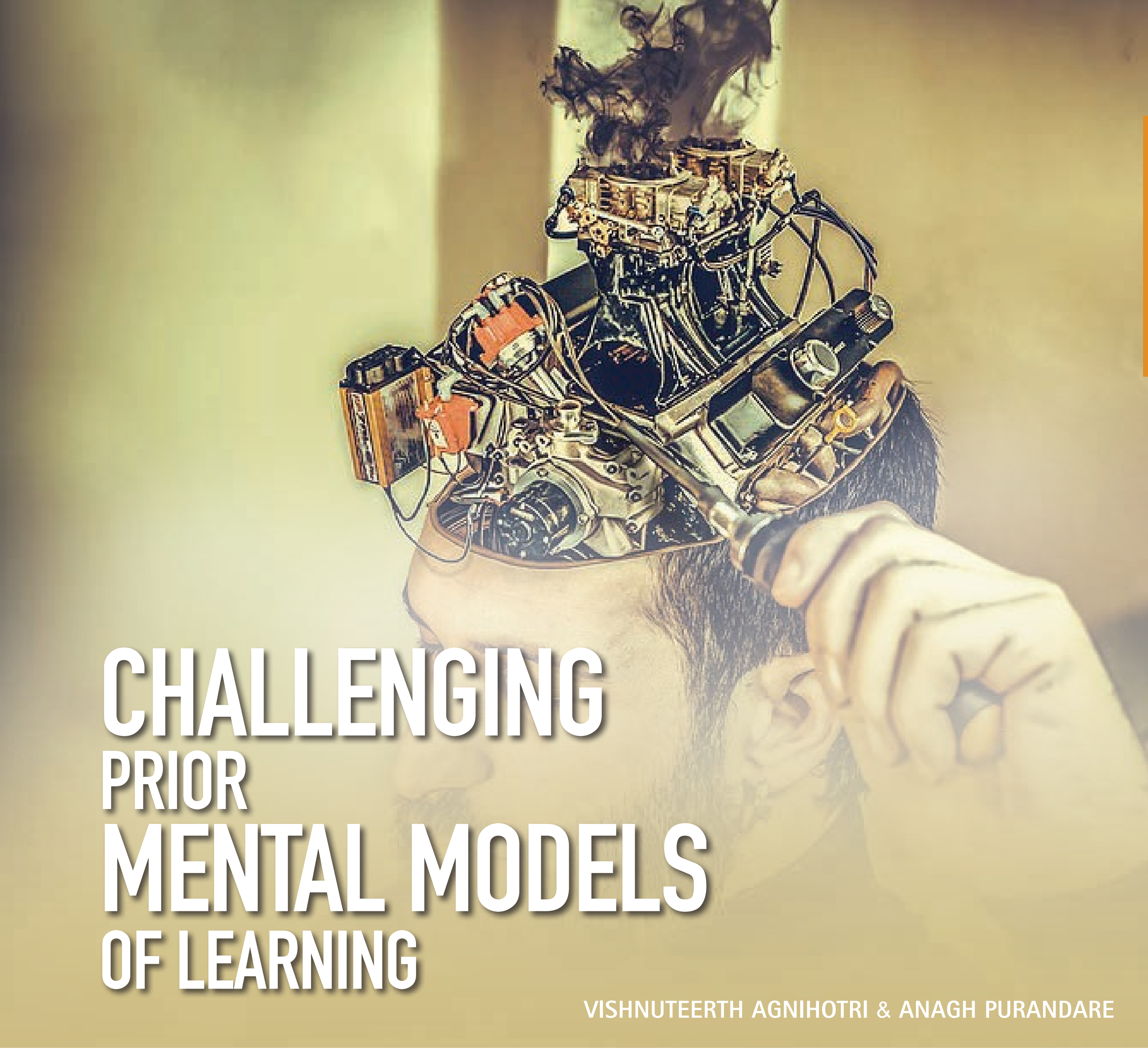

CHALLENGING PRIOR MENTAL MODELS OF LEARNING

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Children enter the science classroom with 'mental models' of real-world phenomena surmised from their day-to-day experiences. Unchallenged, these models can persist into adulthood. Are these models scientifically accurate? How do we help a learner recognise and replace inaccurate models with scientifically accurate ones?

We learn from our observations of the world around us. A two-year-old may learn that food always falls down by repeatedly throwing it up (to our consternation). Similarly, it is through repeated observation that our mature selves learn that a *dosa* will not stick to a pan at a temperature that is high enough, but not too high. These common-sense learnings from everyday observations are useful and, often, even critical for survival. Are they scientifically accurate? Let us examine this through some examples of everyday phenomena.

A metal coin is colder than a wooden spoon in the same room

We bet many of you believe this statement to be true (you certainly don't want some prankster slipping a metal coin down your shirt on a cold winter day)! But, in fact, the metal coin and the wooden spoon will be at the same temperature. Unless one of them had just been brought in from outside, heated, or taken out from a refrigerator. How is this possible? After all, a metal coin feels so much colder to touch than the wooden spoon!

A metal coin may feel colder to touch than a wooden spoon at the same temperature because of the rate at which heat is conducted away from our body to the metal.

Credits: piqsels.com. URL: https://www.pikrepo.com/ftjzy/person-holding-pile-of-coins. License: CC0.

Here's a hint — if you were in a room at 55° Celsius somewhere in the Sahara desert, you would find the metal coin hotter than the wooden spoon. Human beings do not make very good thermometers. When we touch a coin, heat gets conducted away from our body to the metal (a better conductor) at a faster rate than that to wood (a poorer conductor). It is this loss of heat that we interpret as 'feeling colder'. If you used a thermometer, you would find the coin and spoon to be at the same temperature (see **Box 1**).

Not surprisingly, 86 % of Grade VIII students presented with a similar thought experiment (see **Concept Builder: Which is hotter?**) predicted that a metal spoon that has been in hot water for half a day would be hotter than a wooden or plastic spoon given the exact same treatment (see **Table I**).

Box 1. Check out this interesting video, of a researcher trying this 'trick' out on many different people: https://youtu.be/vqDbMEdLiCs.

How would you explain what is happening here?

Which will be hotter after being in hot water for half a day?	Option	Percentage of Grade VIII students who chose this option (%)
The metal spoon	A	86.4
The plastic spoon	B	4.2
The wooden spoon	C	3.9
All three spoons are at the same temperature	D	5.2

Table I. Which is hotter?

Credits: Data based on ASSET, a diagnostic test from Educational Initiatives: http://www.ei-india.com/asset/.

We begin to see things in the dark after we've been there for a while

Again, you may be tempted to agree with this statement. So do many middle school students when presented with a similar thought experiment (see **Concept Builder: Can you see in a dark room?**). Why do we believe this to be true?

Do you remember the many instances when you've been unable to see anything in a 'dark' room immediately after entering it? You may also recall that you were able to see at least a few things in the room after your eyes had a few minutes to adjust to the 'darkness'. Right? Many of us rely on these memories to respond to this statement. Would the same thing happen in a room that is completely dark? Few of us have experienced a completely dark room in our day-to-day lives (there is always some light trickling into any room, like from the moon or a street lamp). So we tend to assume that our observations of relatively 'dark' rooms would hold true — we would be able to see things, at least dimly, after our eyes have had some time to adjust to the darkness. We may even believe that this adjustment would take more time than usual. However, in reality, if no light enters the room, we will not be able to see anything, however much time we spend in it. This is because we only see an object when the light it reflects strikes our eyes.

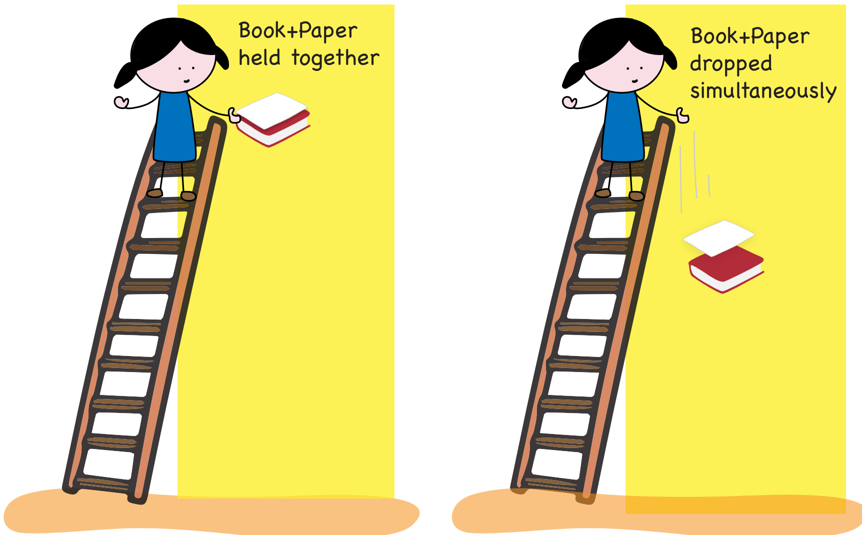
We only see an object when the light it reflects strikes our eyes.

Credits: piqsels.com. URL: https://www.piqsels.com/en/public-domain-photo-zbbol. License: CC0.

A heavier object always falls to the ground faster than a lighter object

Let's suppose that you were to drop a heavy brick and a small book (taped so that it won't open up), from the 3rd floor of a building, at the same time. Which of these do you think will be likely to hit the ground first? If you find this hard to answer, imagine dropping a book (taped to prevent it from opening up) with a piece of paper placed on it. Do you expect the book and paper to reach the ground together? Or, do you expect the paper to 'stay back'?

We have posed these questions (among many others) to several students, teachers, and intelligent adults over the years. Most are surprised at what they find — heavier objects fall at the same rate as lighter ones. For example, 50% of Grade IX students presented with a similar thought experiment (see Concept Builder: **Do heavier objects fall faster than lighter ones?**) predicted that the heavier ball would fall to the ground faster than the lighter one (see **Table II**).



Will the book and paper fall together? Will the paper fall slower?

Box 2. Does some small part of you still doubt that a feather would reach the ground at the same time as a heavy bowling ball in the absence of air resistance?

The only way one can be completely sure of this is by dropping these objects in a vacuum environment (an expensive environment to create). Fortunately for us, this experiment has been tried out (watch this amazing clip from BBC's Human Universe series https://youtu.be/E43-CfukEgs), and has proven this particular mental model inaccurate.

Strangely, many of us have learnt the science behind the phenomenon. We have read how the rate at which objects fall to the ground is independent of their mass and, even, solved problems based on equations that show this. Yet, when presented with a real-world example, many of us continue to believe that heavier objects fall faster than lighter objects. Why does this happen?

One possibility is that we may not have grasped the idea of air resistance. As a result, we interpret our observation of the slow drifting fall of a leaf or a feather as evidence for the idea (or 'mental model') that 'lighter objects fall slower' (see **Box 2**).

Even those of us (including older children and adults) who do understand the idea of air resistance may hold on to this inaccurate mental model. Often, this is because we wrongly extrapolate the idea that heavier objects experience a higher gravitational pull to conclude that they would also fall at a faster rate. In fact, it is quite 'intuitive' to think that a heavier object would fall faster than a lighter one; and, not entirely wrong either (see **Box 3**). However, as a limited idea that applies only to special cases, it is certainly not the general scientific principle that we tend to use it as.

Applying to practice

The three examples we have discussed here reveal some common 'mental models' that children, and even adults, use to interpret real-world phenomena (see **Box 4**). Not only do students come to the classroom with scientifically inaccurate models, they may leave it with their understanding unaltered by what they learn. More often than not, neither the teacher nor the learner is aware of these mental models. It may even appear as if students have clearly understood a scientific concept ... till they face a situation of 'cognitive conflict'. A good science teacher recognizes that working through such confusion and conflict is critical for deep learning.

Let us see how this might play out in the case of the falling objects. First, a teacher could create a cognitive conflict by encouraging students to try out the experiment with the 'paper on the book'.

Which of these balls will fall faster to the ground?	Option	Percentage of Grade IX students who chose this option (%)
Q will fall faster than P because heavier objects always fall faster to the ground	A	43.7
P will fall faster than Q because lighter objects always fall faster to the ground	B	7.8
Both will fall at the same rate because the time taken for an object to fall does not depend on its mass	C	41.9
We cannot say because it depends on the height from which the two fall	D	6.6

Table II. Which will fall faster?

Credits: Data based on ASSET, a diagnostic test from Educational Initiatives: http://www.ei-india.com/asset/.

Observing the slow drift of a feather can lead to the mistaken assumption that 'lighter objects fall slower'.

Box 3. In his book 'The unnatural nature of science', the eminent British biologist Lewis Wolpert argues that *"scientific ideas are, with rare exceptions, counter-intuitive: they cannot be acquired by simple inspection of phenomena and are often outside everyday experience"*

Do you think any of the three examples discussed here support this claim? Why?

Box 4. Would you like to discuss these examples in more detail?

Visit our blog posts:

1. Does a heavier object fall faster? URL: https://tostudentandteacher.wordpress.com/2015/01/17/does-a-heavier-object-fall-faster-to-the-ground/
2. Power of demonstration on unlearning. URL: http://blog.ei-india.com/2015/02/power-ofdemonstrations-on-unlearning/

This experiment may alert students to the existence of air resistance, and create sufficient doubt about what had previously seemed self-evident (that heavier objects fall faster). The teacher could guide a group discussion to help students think through the different factors that might have played a role in the outcome of the experiment. Students may identify factors like the windiness in the classroom; or the relative surface area, hollowness, and roughness of the two objects. Having done this, the teacher could encourage students to test these factors by designing and performing a variety of experiments with different objects. These would help progressively clarify student ideas till they arrive at the conclusion that lighter objects do indeed fall at the same rate as heavier objects.

Key takeaways

- Children may enter the classroom with scientifically inaccurate mental models of natural phenomena.
- Unless recognized, these mental models may remain unaltered by the concepts students are introduced to in the science classroom.
- Teaching–learning processes that recognize this possibility attempt to bring such mental models to the surface, so that the learner, as well as the teacher, becomes aware of them.
- Teachers can use a variety of methods, discussion, and supporting exercises to help the learner replace incorrect prior mental models with scientifically accurate ones.

Notes:

1. This is a revised & reformatted version of an article (with the same title: 'Challenging Prior Mental Models') that first appeared under the section 'Myth or Fact' in the November 2015 issue of i wonder.
2. Source for the image used in the background of the article title: https://pixabay.com/photos/mechanical-brain-man-machine-2033446/. Credits: aytuguluturk, Pixabay. License: CC0.

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