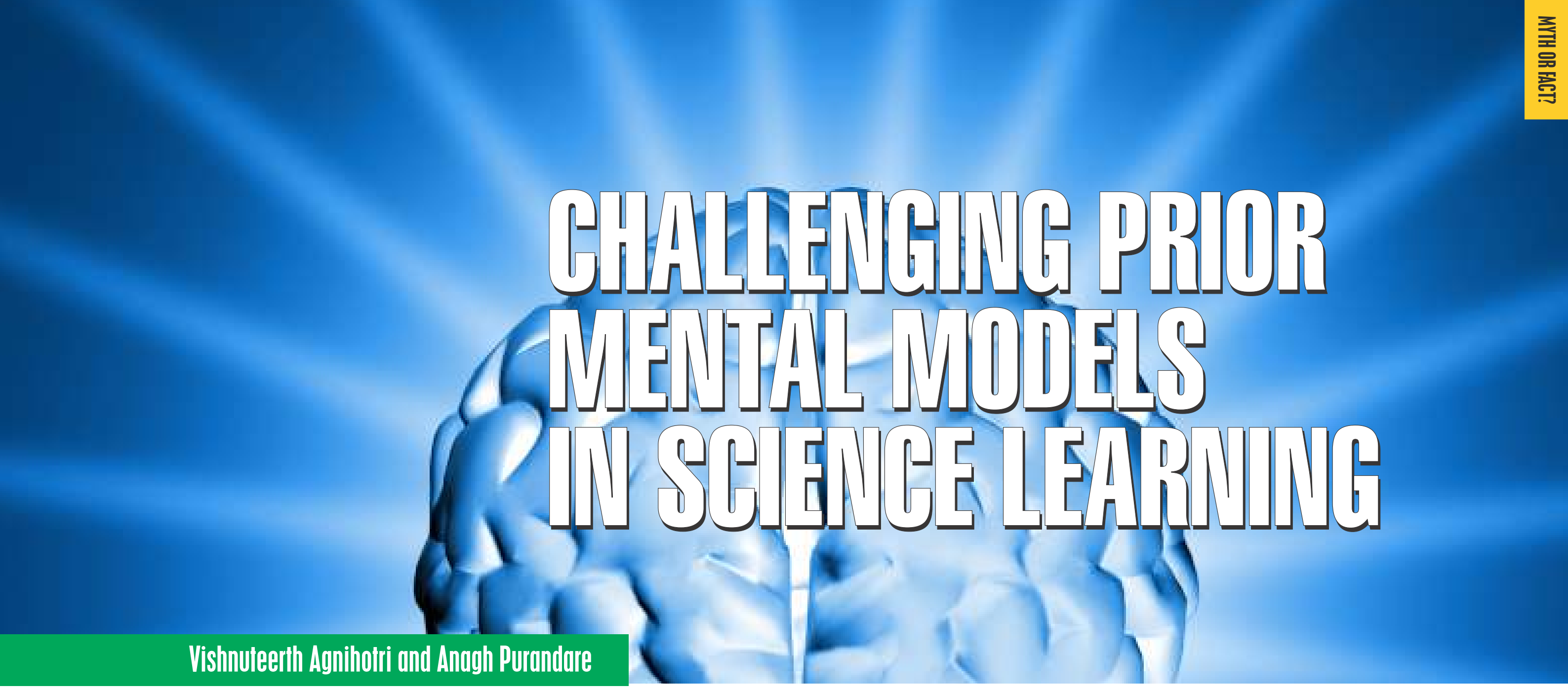


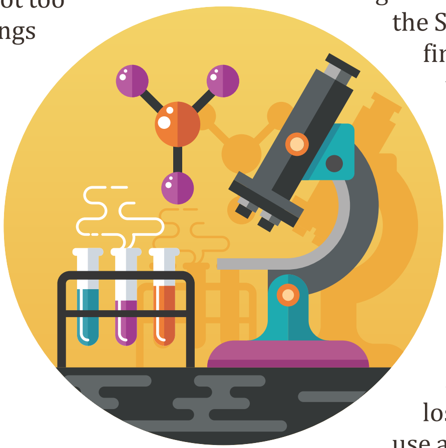
CHALLENGING PRIOR MENTAL MODELS IN SCIENCE LEARNING

Vishnuteerth Agnihotri and Anagh Purandare

Are all that children surmise from their day-to-day experiences, actual scientific truth? In this article, we discuss three examples that show how children have such 'prior mental models' before they enter classrooms, and how these could persist, even into adulthood. We also discuss potential ways to help learners replace these 'prior mental models' with correct scientific models.

Introduction

Observations of the world around us are very important for learning. A two year old, to our great consternation, may learn that food always falls down by repeatedly throwing it up; our own mature selves may learn that dosa will not stick to the pan if the temperature is high enough, but not too high. These common-sense learnings are very useful and often even critical for survival, but are such learnings gathered from observations and common sense, scientific facts? Let us examine these by exploring some everyday phenomena.



Example 1

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

We bet many of you think the metal coin is colder - 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 are at the same temperature (unless one of them is being heated, or has been put in the refrigerator, or has just been brought in from outside). How could that be? After all, the metal coin feels so much colder to touch than the wooden spoon!

Here's a hint as to why this might be happening - if you were in a room at 55 degrees Celsius somewhere in the Sahara desert, you would find the metal coin hotter than the wooden spoon.

What is happening here is that human beings do not make very good thermometers - when we touch a metal coin, heat gets conducted away from our body to the coin at a faster rate (as compared to wood which is a poorer conductor), and it is this loss of heat we sense as 'cold'. If you use a thermometer, you will find that both are actually at the same temperature.

This is a common misconception - 86% of class 8 students* think that a metal spoon would be hotter than a wooden spoon after both of them have been in hot water for half a day.

** The data is based on ASSET, a diagnostic test from Educational Initiatives.* http://www.ei-india.com/asset/

A metal spoon, a wooden spoon and a plastic spoon are placed in hot water for half a day. The water is maintained at the same temperature throughout.

At the end of the experiment, the objects are taken out and their temperature is measured immediately. Which of the following is likely to have the highest temperature?

Option	Option	Performance
A	the metal spoon	86.4%
B	the plastic spoon	4.2%
C	the wooden spoon	3.9%
D	(All the three spoons will have almost the same temperature.)	5.2%

Also check out a very interesting video at https://youtu.be/vqDbMEdLiCs , where a researcher tries this 'trick' on various people, and explains what is happening.

Example 2

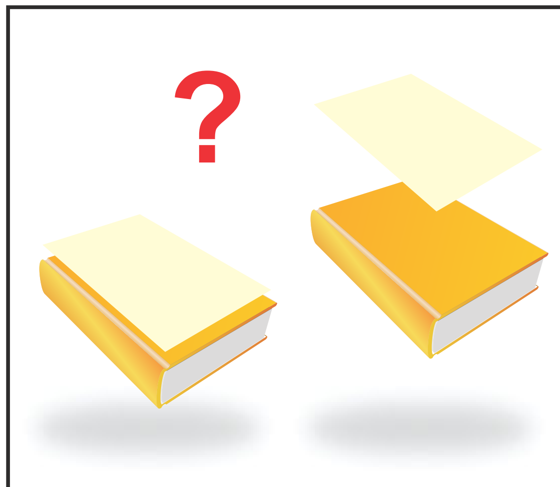
We can see things in the dark if we wait for some time.

You are in a room which is completely dark - do you think you will be able to see a chair in front of you after a few seconds? Again, when you are asked this question, you might recall that whenever you have entered a dark room, you have not been able to see anything immediately, but after a few minutes, your eyes have adjusted to the light in the room, and you start to see a few things at least. Right? So you might answer "yes- I will see the chair after a while". But what if the room is completely dark? If there is no light entering the room, then however much time we might spend in the room, we will not see anything, because to see anything, we need some light reflected from the object to enter our eyes. In our daily experience, we never experience a completely dark room (there is always some light trickling into any room - maybe moonlight or from a street lamp) and therefore, we tend to assume that if we wait long enough, we would be able to see things in the dark, at least dimly.

Example 3

A heavier object always falls faster than a lighter object

Suppose you are holding a heavy brick in one hand, and a small book in the other (taped so that it won't open up), and are standing on the 3rd floor of a building. If you release both of them at the same time, which of these is likely to hit the ground first? It may be hard for you to try this now, so let's try another one - what do you think would happen if you place a sheet of paper on top of a book you are holding, and drop the book (tape the book so that it doesn't 'open out')? Do you expect them to fall together, or do you expect the paper to 'stay back' and fall slower to the ground? Answer this question, and verify your answer by actually trying this out before you read further... What did you find? Surprised?



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

We have tried the above three questions (among many others) with several students, teachers and intelligent adults over the years, and most are surprised at what they find - the metal coin and the wooden spoon being at the same temperature, not being able to see in the dark, or heavier objects falling at the same rate as lighter ones.

For example, look at another ASSET* question below, almost half of the class 9 students think that the heavier ball will fall to the ground faster:

Two balls, P and Q of equal size but unequal mass (P weighs 5 kg and Q weighs 10 kg), are hanging from strings as shown in the diagram. The strings are simultaneously cut. Which of them would fall to the ground faster and why?

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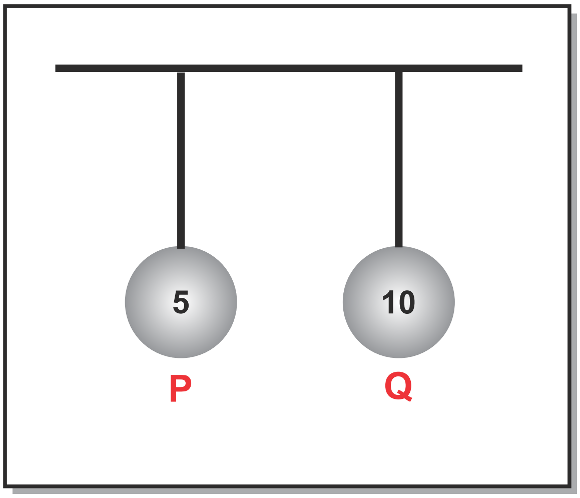
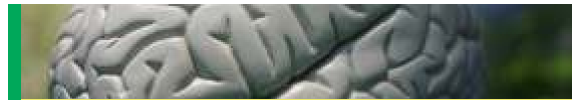


Option	Option	Performance
A	Q will fall faster than P because heavier objects always fall faster to the ground	43.7%
B	P will fall faster than Q because lighter objects always fall faster to the ground	6.9%
C	Both will take the same time because the time taken to fall does not depend on the weight	41.9%
D	We cannot say because it depends on the height from which they are falling	6.6%

Why does this happen? Often, we have learnt the science behind the phenomenon - why is it still so hard? Let us examine this by going into more detail.

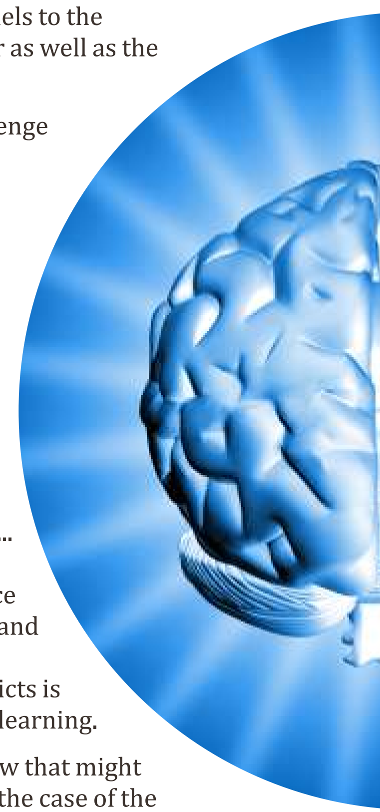
Why do we continue to believe that heavier objects fall faster than lighter objects, even though we might have read that they fall at the same rate or even solved many problems using equations that show they do? This probably happens because we do not grasp the idea of air resistance - air being invisible, seeing the slow drifting fall of a leaf or a feather, we may interpret such observations to form the idea (or 'mental model') that 'lighter objects fall slower'. Even if we understand the idea of air resistance (which older children or adults do), we may still be wrongly extrapolating the idea that heavier objects experience a higher gravitational pull to conclude that they would also fall at a faster rate. It is quite 'intuitive' to think that a heavier object will fall faster than a lighter object and not entirely wrong - it is just a limited idea that applies only in special cases, and is certainly not a general scientific principle.

One of the main drawbacks of traditional science teaching is that it does not recognise that students come to the classroom with "prior mental models", and that the process of teaching-learning, requires:

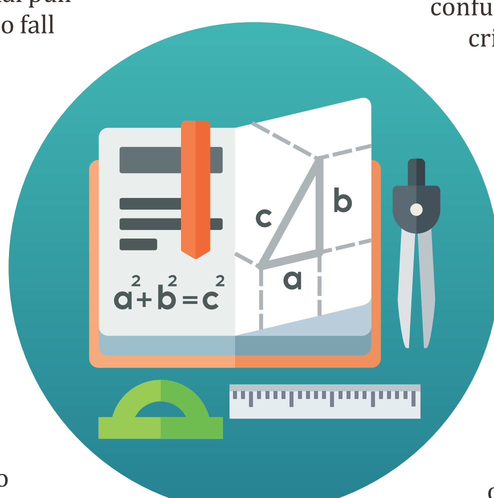


"Scientific ideas are, with rare exceptions, counter-intuitive: they cannot be acquired by simple inspection of phenomena and are often outside everyday experience."
- Lewis Wolpert, The unnatural nature of science

- Bringing such mental models to the surface, so that the learner as well as the teacher are aware of these
- Devising methods to challenge these mental models
- Discussions and exercises that allow the learner to replace her prior, incorrect, mental models with correct scientific ones.



But, more often than not, neither the teacher nor the learner is aware of these mental models, and everything may appear to be clearly understood... till you face a situation of 'cognitive conflict'. A good science teacher knows that recognizing and working through the confusion and conflicts is critical for deep learning.



Let us see how that might play out in the case of the falling objects. First, a teacher may create a cognitive conflict by asking students to do the experiment with the 'paper on the book' described above. That might perhaps alert students to the existence of air resistance and create sufficient doubts in their mind on what was previously self-

* The data is based on ASSET, a diagnostic test from Educational Initiatives. http://www.ei-india.com/asset/

evident to them (that heavier objects fall faster). Now a teacher might help students to think through all factors that might play a role in the process - through a discussion, students might identify factors like - surface area, hollowness, roughness, windiness of conditions etc. Having done this, students would then perform a variety of experiments with different objects till they come to a deep conclusion based on these that lighter objects do indeed fall at the same rate as heavier objects.

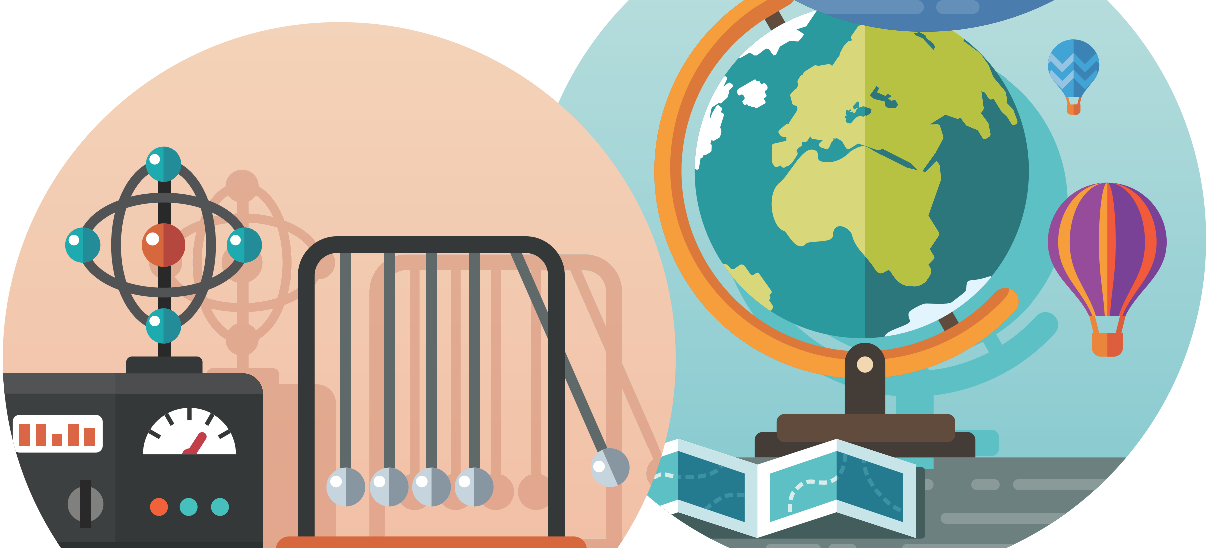
But does that 1% doubt still linger in your mind about whether a feather would reach the ground at the same time as a heavy bowling ball if air resistance were not present? What would it take to be 100% sure - the only way is to drop these objects in a vacuum environment - where would you find one! Fortunately for us, this expensive experiment has been done - watch the amazing clip below from BBC's Human Universe series and can be accessed here - https://youtu.be/E43-CfukEgs.

References

You can also visit our blog posts that discuss one of the above examples in details:

https://tostudentandteacher.wordpress.com/2015/01/17/does-a-heavier-object-fall-faster-to-the-ground/

http://blog.ei-india.com/2015/02/power-of-demonstrations-on-unlearning/



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