Issue 04 | January 2018
Half-Yearly | Bengaluru

# i wonder...

## Rediscovering School Science

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### Where do we come from?

What are we? Where are we going?

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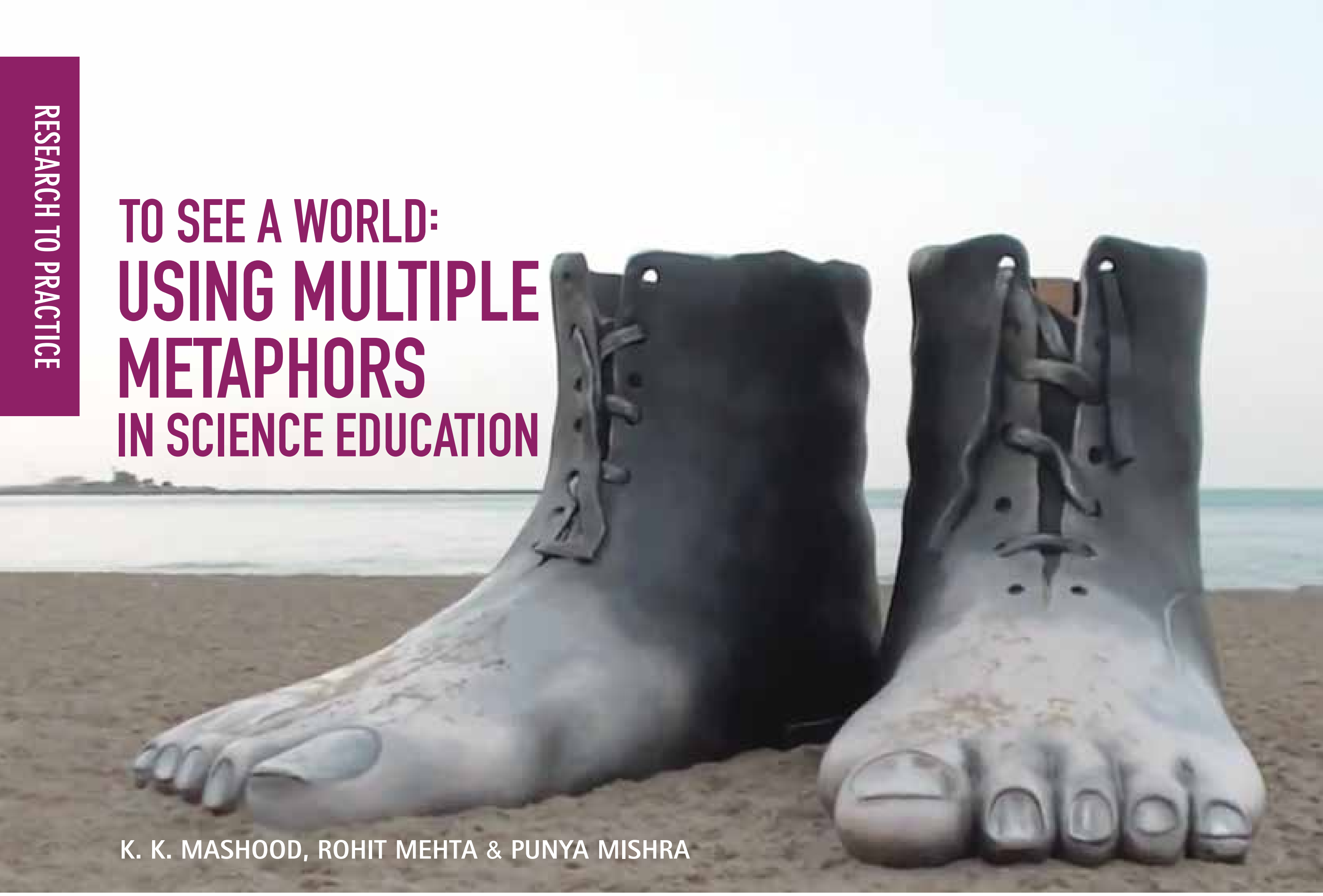

# TO SEE A WORLD: USING MULTIPLE METAPHORS IN SCIENCE EDUCATION

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**Metaphors play a crucial role in how we conceive and understand new concepts and ideas. Using insights from science education research on the teaching of energy, this article illustrates how the use of multiple metaphors can help present dry, abstract and complex science concepts to students in more lively, engaging and richer ways.**

*"Our ordinary conceptual system, in terms of which we both think and act, is fundamentally metaphorical in nature".*
— George Lakoff.

*"To see a world in a grain of sand*
*And a heaven in a wild flower*
*Hold infinity in the palm of your hand*
*And eternity in an hour".*
— William Blake.

How do we learn something new? It can be argued that the only way we can understand something new is in terms of what we already know. Lying at the heart of metaphors, this argument is particularly significant when we seek to understand abstract ideas. For instance, consider the idea of energy, a complex foundational concept that is discussed seemingly differently in different domains of science. The challenge is to connect this abstract idea to something that learners already know; and, yet, do it in a way that prevents unitary, simplistic understandings.

As educators know, teaching a human being is not like programming a robot or a computer to do something. In the latter case, all we need to do is provide accurate instructional inputs. There is no room for interpretation or imagination, or for alternative conceptions or misconceptions. In other words, what is 'told' is 'taken' as it is, provided there are no technical glitches or errors. Teaching a human being, on the other hand, is far more complicated, even when we do it with (what we believe is) absolute clarity. Consider the following remark from Carl Wieman, a Nobel-prize winning physicist turned education-researcher[1]:

*"When I first taught physics as a young assistant professor, I used the approach that is all too common when someone is called upon to teach something. First, I thought very hard about the topic*

*and got it clear in my own mind. Then I explained it to my students so that they would understand it with the same clarity I had. At least that was the theory … [But] whenever I made any serious attempt to determine what my students were learning, it was clear that this approach just didn't work. An occasional student here and there might have understood my beautifully clear and clever explanations, but the vast majority of students weren't getting them at all".*

Why does this happen? It is unlikely that someone like Wieman did not know the physics he was trying to teach, or lacked clarity in its exposition. The real reason could be the underlying complexity of human cognition. Rather than learning anything new exactly as it is told to us, we try to comprehend it using what we already know. Learners are active constructors of knowledge; and a range of factors (such as their prior experiences, social context, linguistic ability, and emotional setup) can influence how they receive, store and retrieve information.

The fact that learning builds on, or is constrained and framed by, what we already know is often taken to be a problem, since it widens the factors that educators need to consider as we design our lessons. However, we argue here that, as educators, we need to accept this, and learn to harness it to our advantage.

Metaphors offer one way of building on prior knowledge to explain new ideas. In fact, all teachers have knowingly or unknowingly used metaphors at some point in their work. However, single metaphors can cause a seductive reduction in complexity of an otherwise rich idea (see **Fig.1**). In this article, therefore, we focus on a strategy of using multiple metaphors to explain complex scientific ideas. We ground our discussion of this strategy in one specific example — that of teaching about energy.

## Teaching the concept of energy

Energy is one of the most fundamental and overarching concepts in science. Students learn about energy in school in a variety of contexts. In biology, the idea of energy is the key to understanding important topics such as photosynthesis and nutrition. Energy in chemistry is integral to understanding concepts such as chemical bonds. In physics, energy is discussed in terms of work, in the form of kinetic and potential energy. Often the concept of energy, irrespective of what aspect of science is being taught, is introduced by giving textbook (or clichéd) definitions like, energy is 'the ability to do work'.

We reason that such an approach hardly encompasses or conveys the underlying conceptual richness of this important and complex concept. In addition, students hear the same word in different classes or contexts, but are not provided opportunities to connect its seemingly

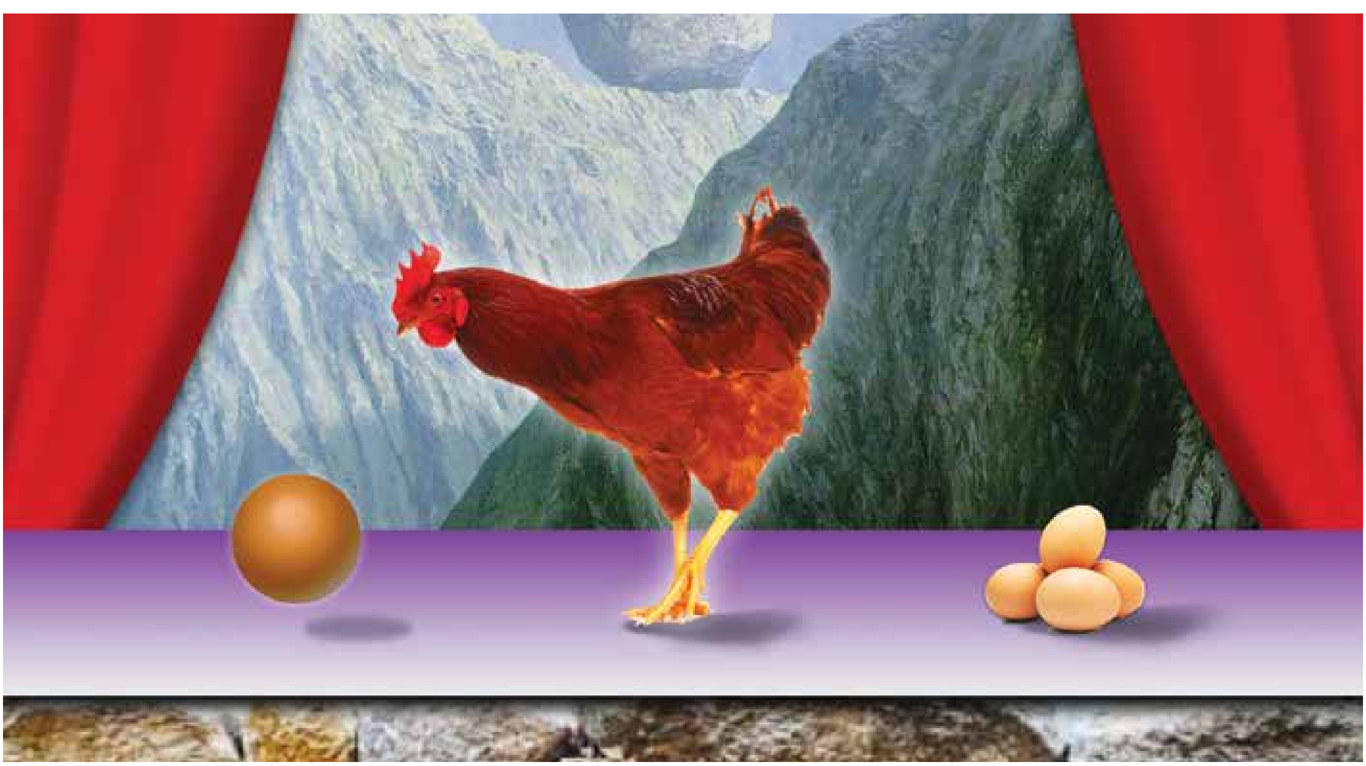

**Fig. 1. The seduction of using single metaphors:** using just one representation reduces the complexity of a rich idea.

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different uses. Thus, students can end up having an incomplete and fragmented understanding of this concept. And, if these misunderstandings are related to core science concepts (such as energy), it can lead to further confusion and misconceptions down the road.

## Multiple metaphors of energy: The research perspective

Rachael Lancor's research provides a perspective into the range of concepts that underlie the concept of energy, providing insights on how it can be taught effectively[2,3]. She considers how physics, chemistry, and biology textbooks (along with science education literature) conceptualize energy, and through this gives a picture of the web of ideas essential to understanding the concept. This study finds that each discipline, on its own, focuses only on a subset of the overarching concept. It is only by providing a framework that integrates these seemingly distinct views that we can hope that students truly understand it.

Lancor begins by stating five main characteristics associated with the concept of energy that students need to understand. These, relatively abstract ideas, are:

1. Energy is conserved.
2. Energy may dissipate from a system over time.
3. Energy can be transformed from one form to another.
4. Energy is transferred between parts of a system, and that
5. Energy could be received by a system from another source.

Lancor then follows this up with an analysis of introductory science textbooks (across domains such as physics, biology, and chemistry) to see how these abstract ideas are explained. In brief, she identifies six different key conceptual metaphors that ground the abstract ideas in ways that make sense to students. These are:

1. Energy, like money, can be accounted for and tracked.
2. Energy can take different forms, and changes from one to another.
3. Energy can flow like water through a pipe.
4. Energy can be carried by living organisms as well as inanimate entities like electrons.
5. Energy, like oil in a faulty machine, can be lost.
6. Energy can be stored in devices like a battery or a wound-up spring.

Of course, each of these metaphors, if used in isolation, leads to the distinct possibility that students develop a limited understanding of the nature of energy, and how it plays out across different scientific disciplines. It is here that the idea of weaving multiple metaphors together can help convey both the richness of the concept and prevent students from holding on to


**Fig. 2. The six metaphors for energy.**

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one metaphor as being the only way to understand a concept (see **Fig. 2**).

What is important to note is that each of the six metaphors of energy highlight only some of its five main characteristics, while obscuring others. For instance, treating energy as a substance that can be tracked and accounted highlights its conserved quality but obscures its ability to be transformed from one form to another. On the other hand, the metaphor of energy as a substance that can be lost highlights the fact that it can dissipate, but obscures its ability to be conserved. Picking one or a few metaphors would therefore result in a situation like that of the blind men trying to describe the elephant – each one understands only a part and can never agree to the overall. To develop a coherent understanding of energy would require careful consideration of all the various characteristics associated with the concept. This necessitates weaving multiple metaphors together to reach a richer understanding of the whole picture.

## Implications for instruction

Energy is often introduced in school classrooms by short definitions, like, the one stating that it is 'the ability to do work'[2,3]. This is not only ineffective, but provides students with an incomplete picture about a rich, critically important, foundational concept in science. Students merely memorize such clichéd statements and regurgitate them during examinations. This also has the implicit danger of giving students as well as teachers a false sense of knowing. A discussion of energy based on multiple metaphors may help resolve some of these issues. In addition to deepening student understanding, it can also facilitate their ability to connect ideas and disciplines. Included below are some guidelines on how to implement this strategy in science classrooms:

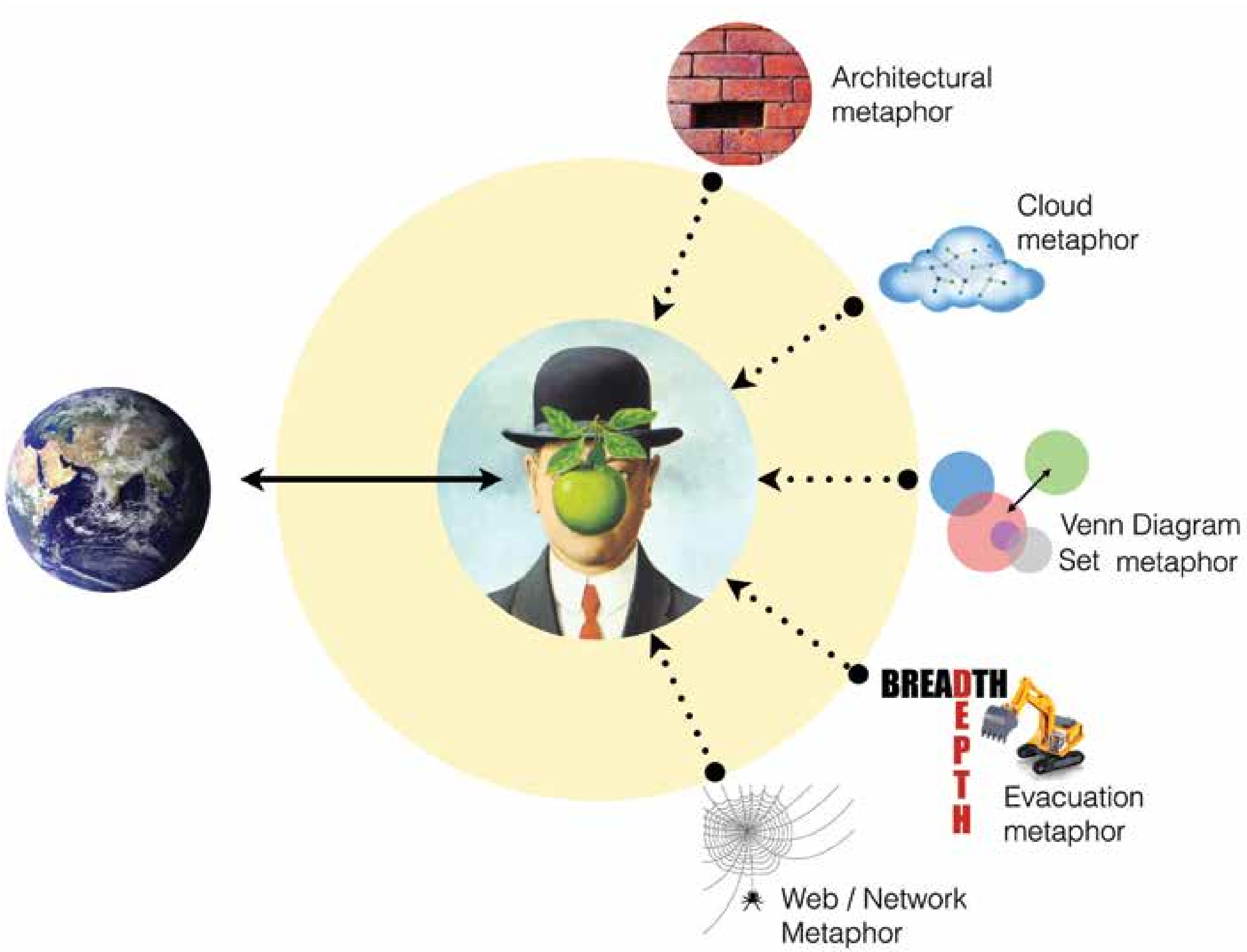


**Fig. 3. Multiple metaphors of knowledge in understanding the world.**

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### (a) Learning to think like scientists.

Unlike scientists and experts, students are less likely to be proficient with the nuances associated with language. They may not have the depth of understanding to precisely interpret metaphors, and may take things literally. What we often refer to as misconceptions or alternative conceptions pertaining to energy are mostly imprecise re-conceptualizations of metaphors. The expertise and deeper understanding to appreciate these metaphors cannot be obtained overnight. It requires continuous engagement and development over time. It is, therefore, important to demonstrate the iterative process of scientific method.

**How to implement?** Feynman's lectures on physics provide an example of building arguments pertaining to energy conservation[4]. He starts with the story of the fictional character of Dennis the Menace playing with a set of blocks. With each block, the story containing metaphorical descriptions keeps growing in complexity, with mathematical equations making their entry towards the end. Similarly, there should be considerable engagement with the concept of energy in terms of metaphors. Once it is ensured that students have a considerable grasp with the metaphorical language and discourse pertaining to energy, the teacher may bring in formal definitions, equations, and numerical problems. Encouraging students to explore connections between non-mathematical and mathematical concepts will further boost coherence and rigor. This may often require revisiting the metaphors and a strengthening of concepts iteratively. This can be done in small groups.

### (b) Transdisciplinary thinking.

Concepts like energy are present across disciplines. However, how the idea of energy is discussed in physics may differ (at least at a surface level) from how energy is discussed in biology or chemistry. A specific topic in a discipline may afford a certain metaphor[2]. A coherent, in-depth understanding of the concept requires reconciliation between its apparently different disciplinary manifestations. Unfortunately, this conceptually challenging task is often left wholly to students. A discussion based on multiple metaphors facilitates reconciliation between energy in physics, chemistry, and biology, and has the additional benefit of providing richer language and conceptual structures to talk and reason about these ideas.

How to implement? Identify the metaphors associated with a specific description of energy. For example, biology discusses the flow of energy through ecosystems. The metaphor of energy as a substance that flows like water through a pipe is relevant to this context. On the other hand, discussion of a stone rolling down a hill is found in physics. Here the metaphor of energy as a substance that changes from one form to another is apt as potential energy is getting converted to kinetic energy. Highlight the fact that though the metaphors are different, there is an underlying connection between them. It is only when we hold them together coherently that we achieve a complete picture of energy as a concept. Talk to other science teachers in your school and prepare complementary metaphors for physics, chemistry, and biology.

## Conclusion

Our understanding of the idea of knowledge itself is metaphorical in nature (see **Fig. 3**). For instance, viewing knowledge as a web or network has very different consequences from having an architectural metaphor. Going deeper into these different metaphors is beyond the scope of this article, but something that all educators need to keep in mind.

The ability to connect ideas and disciplines is important for multiple reasons[5]. To be able to see the same thing from different perspectives and fathom the underlying unity between apparently distinct ideas is a wonderful experience. We can help our students climb to a vantage point which allows them to appreciate concepts, like energy, beyond the confines of textbook definitions and equations. The foundations for transdisciplinary thinking can be built as early as at the school level. And, as illustrated with the concept of energy, the use of multiple metaphors to teach science has the potential to facilitate such connections between and across disciplines.

**Note:**

1. All the illustrations in this article were created by Punya Mishra, inspired by the Belgian surrealist artist René Magritte. Magritte's art often points to the limitations and arbitrariness of using language to understand the world and thus provided a rich source of images to explore the idea of using multiple metaphors in science education.
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