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Bringing the Laboratory into the Classroom: Bringing Inventive Thinking into the Mind

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Neeraja Raghavan

There is no doubt that a good laboratory will enrich the learning and teaching of science. While this is undisputable, it is possible to transform the teaching and learning of science even without a full-fledged laboratory, provided one can draw upon everyday experiences, commonly asked questions, easily available materials and just a few tools that may need to be purchased.

If we map the journey of a typical science class, we will probably see something like what is shown below:

1. Teacher first reads through the syllabus
   ↓
2. Teacher reads the relevant portion of the text
   ↓
3. Teacher plans the lesson(s) to cover that particular topic
   ↓
4. Teacher covers the topic in the allotted number of periods
   ↓
5. Teacher gives worksheets and/or a test to assess learning levels

In the above work flow, the role of the teacher is that of a lecturer, and (s)he will doubtless cover the topic efficiently, if (s)he moves as planned. The role of the child is largely that of a passive recipient, who is called upon to listen to and absorb whatever was taught, only to repeat it (preferably verbatim) during the assessment. Conspicuous by their absence are the following: experiential learning, the triggering of curiosity, the articulation of questions, the performing of experiments, the noting down of observations, the 'seeing' of a pattern in data collected, the drawing of logically consistent conclusions and finally, the shift in thinking that results from a transformative experience. In order to show that none of these processes is too far - fetched - even in Class IV - in a school without a laboratory, I shall first draw upon a research paper which describes a very simple experiment. A fourth grade teacher had to teach 'heat' to her students, and she chose not to adopt a route such as the one delineated above. Instead, she began by asking the nine-year-old children (in cold Massachusetts) about their experience of warmth and heat, in the nine winters that they had faced so far. (See text box below)

"Sweaters are hot," said Katie.

"If you put a thermometer inside a hat, would it ever get hot! Ninety degrees, maybe," said Neil.

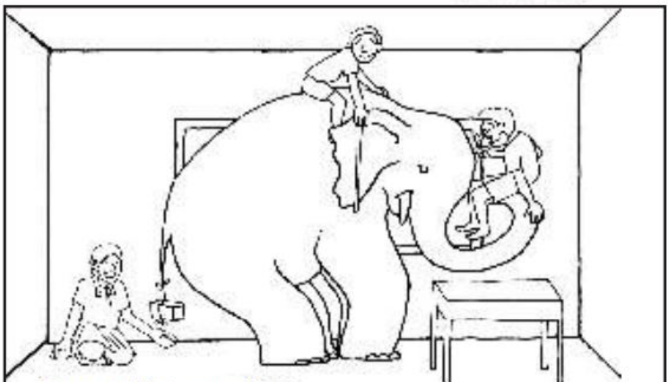
"Leave it there a long time, and it might get to a hundred. Or 200," Christian added.

Confronted with the children's preconceptions in so direct a manner, this talented teacher decided to have the class test out each one of them. She did this by having the class place thermometers in hats, sweaters and even a rolled up rug. When children found that the first few readings on the temperatures did not show any difference, they were convinced that they needed to leave the thermometers in longer. (Here, the resistance that we normally encounter in giving up a pet premise is palpable!) So they left the thermometers overnight and came back the next day, sure that the temperatures would be soaring! Instead they found no demonstrable change. Still, they were not yet ready to abandon their ideas. A less talented (or more harried) teacher would probably have stopped at this point, corrected them and explained the reason why the temperature did not rise. Instead, this teacher empowered her students to 'own the problem' and continue pondering, testing and discussing their ideas until they were themselves ready to give up their erroneous belief and incorporate new knowledge. What is remarkable about this class? First, the teacher was less focused on covering the syllabus than on uncovering students' preconceptions. Next, she was wise enough to allow the learning to unfold at its own pace, by testing the premise of each child, and waiting for them to give up their incorrect preconceptions only when they were convinced of their incorrectness. I can almost hear the teacher's lament: "But we can't possibly do this for each and every topic! We will never finish the syllabus in this way!" Yes, you probably won't. But to your surprise, you may find that you won't need to. Because in the process of nudging the children

Science Communicator's Forum (SCF) has innovated cost-effective ways to convey scientific concepts. For instance, since prisms are expensive, members of SCF use a glass of water and an inexpensive laser light to demonstrate the internal reflection of light. Similarly, in order to explain the concept of land and sea breeze, students are asked to take a tumbler and put some water on one side and sand on the other side. The tumbler is then left outside in the sun. An incense stick is lit and placed in between the sand and water. Once the sand and the water are warm, the movement of the smoke indicates which way the breeze is blowing. This way, students get to learn the basics of how sea and land breeze occur. [from http://timesofindia.indiatimes.com/Education/Beyond_the_chalk talk_method_of_teaching/articleshow/3935253.cms Times of India 5 January 2009, Beyond the chalk-talk method of teaching)

to think through their own preconceptions, the immense learning that has been effected will stand the class in good stead when the next topic has to be DIScovered! (not covered.) [Besides, by covering the entire syllabus under the thick hood of efficient transaction, one is not effecting a change in thinking at all: and how, then, can one claim to be teaching science?] Thirdly, the link between scientific thinking and one's everyday life are so obvious in this class, that there is no need to teach that chapter on 'Scientific Temper' (which usually forms a mandatory part of the syllabus) and now, doesn't that reduce the 'portion' to be 'covered'?!

It is important to see how the shift in thinking can only occur when the teacher begins to view science more and more as a 'Verb', and less and less, as a 'Noun'. In getting children to 'own' their premises, one is empowering them to hold certain beliefs, something we never do when we are only focused on


Classroom lab-to remember science like an elephant's memory.

'covering' the syllabus. Then, as we lead the children into enquiring into these strongly held beliefs, we are moving from a secure ground where the child is not threatened: instead, the child is confident enough to test his/her premise. Would it now be unreasonable to expect such a child to carry on with this practice of testing out dearly held beliefs, even outside the classroom? Surely not! It is, therefore, desirable to bring in this process of thinking into the science class, and much of this does not require a hi-fi laboratory, at least for Class IV and V.

Some suggested ways of developing Observation, Enquiry and Thinking Skills in Class IV and V are described in the following section, through the example of a Leaf.

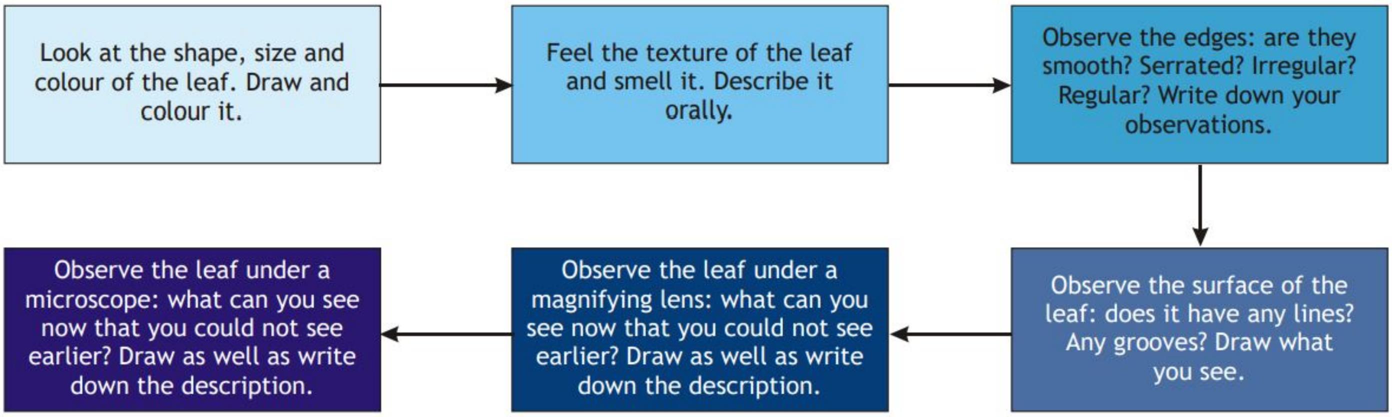
In addition, it is important that the teacher goes to class prepared with at least a few names and biographies of scientists who have worked on the topic to be taught (in this example, leaves and plants) so as to be able to connect at least some of the questions asked (by the children) to those asked by scientists down the ages. Beginning with a set of stories about scientists, (to be culled from references, some of which are suggested elsewhere in this issue), the teacher must show how those scientists looked at certain things and then asked certain questions, just like the children are now doing in class. [For example, in connection to some of the questions posed for a leaf, here are some related scientists and discoveries, which took this writer less than ten minutes to cull from the Internet:

■ While studying an orchid, botanist Robert Brown (1831) identified a structure within the cells that he termed the "nucleus."

■ In the 1770s, Jan Ingenhousz discovered that plants react to sunlight differently than shade and from the underpinnings of this; the understanding of photosynthesis was born.

■ From the fifteenth century onwards, early European explorers who went on sailing expeditions around the world, noticed that the tropics host a much greater variety of species. Answering why this is the case allows today's scientists to help protect life on Earth.]

Guidelines for gradually honing observation skills: (increasing intensity of colour of textbox shows increased intensity of observation) we are taking the example of a leaf:



Guidelines for gradually honing enquiry skills: In the example of a leaf, the nature of questions that can be drawn out/discussed could be of the type:

- Why is this leaf shaped thus?
- What are the uses of this leaf?
- When does it grow?
- Where does it grow?
- When does it die?
- What does it need to grow?
- Why does/doesn't it smell?
- Does it have brothers and sisters like I do?
- Does it belong to a family like I do?
- What is this leaf made up of?
- Can I eat it?
- Who can eat this leaf?
- Does its shape, size or colour change over time?
- Can its shape, size or colour be changed by planting it in different soils? By giving it different food?
- Do insects like to sleep on it? Eat it?
- How can we protect the leaf from insects? Animals? And so on.

A word of caution: In the commonly-experienced hurry to arrive at the 'right answer', too often the brilliant question is missed, the sustained enquirer is ignored, and the exercise turns into one of ticking right versus wrong answers. It is strongly recommended therefore that the flood of enquiry be sustained through active encouragement of those who kept asking, right until the end of term/year.

Thinking: Following the flood of enquiry, it may be opportune (depending upon the level of understanding and interest of the class) to stoke the fire further through discussion. This is an important part of the process of drawing the child into the fold of timeless scientific enquiry, by connecting the questions asked by the child to prior questions/discoveries or presentday unknowns. Again, it is important to bear in mind that without unduly hurrying the child to think of answers to the questions asked in the Ask stage, this Think step should be used well to roll the questions over with the tongue, as one would a piece of candy. Suck it, taste it, feel its juice pouring down your throat! The important thing here is not to worry about answers, but to allow for bold and free thinking around each question, perhaps again in the form of further questions.

Questions spring up in the mind from our own level of understanding and knowledge. Therefore, the teacher would do well to pause and take some time in looking at questions asked through the screen of the following filters, continuing with the example of the leaf:

1. A question like "Why is this leaf green?" could be connected by the teacher to why anything appears coloured, do we all see the same colour, what causes the perception of colour in each person, etc. Thus, the child can be asked to draw a chain of questions, each inside a bubble, as it were, and see how one question in the first bubble is leading to the spurting of so many more questions.

2. Questions on the shape and size of the leaf can be connected by the teacher to our own shapes and sizes, that of animals and other parts of creation, and the class can together muse on possible links between function and shape/size of any creature. Would an elephant be an elephant if it were not so huge? Would a jackfruit be as tasty if it were not so big? etc.

3. Questions like 'How does the leaf grow?' could be connected to the story of the discovery of photosynthesis (see Box 1 below), which the teacher needs to go prepared with, to class.

Box 1: Photosynthesis

Too often, this topic is taught as if the entire mystery was just revealed to scientists by the flick of a wand. This writer visited a very interesting website: http://www.juliantrubin.com/bigten/pathdiscovery.html and culled the following information in less than twenty minutes of surfing. The teacher would do well to collect four or five such stories before taking up a new topic, so as to awaken the scientist within the child.

Is Water the Source of Energy in Plants?

Experiment I

Jan Baptista van Helmont, Flemish physician, chemist, and physicist, in the 1600s carried out a famous experiment by growing a willow tree in a pot for five years. At the end of this period the tree had increased in mass by 74 kg but the mass of the soil had changed little. Van Helmont believed that water was the source of the extra mass and the plant's source of life. What could the other possibilities be? How would you test out each of those possibilities?

(Sequence of experiments as they were performed historically, follows.)

Experiment II

John Woodward, a professor and physician at Cambridge University in the late 1600s, tried to design an experiment to test Van Helmont's hypothesis that water was the source of the extra mass. In a series of experiments over as many as 77 days, Woodward measured the water consumed by plants. For example, one plant showed a mass gain of about 1 gram, while Woodward had added a total of almost 76,000 grams of water during the 77 days of plant growth - this was a typical result. Woodward correctly suggested that most of this water was "drawn off and conveyed through the pores of the leaves and exhaled into the atmosphere". So the hypothesis that water is the nutrient used by plants was rejected. (Teacher can describe the experiment and ask students to draw the inference.)

The Interaction of Plants With Air

In August of 1771, Joseph Priestley, an English Chemist, put a sprig of mint into a transparent closed space with a candle that burned out the air (oxygen was not discovered yet) until it soon went out. After 27 days, he relit the extinguished candle again and it burned perfectly well in the air that previously would not support it. And how did Priestley light the candle if it was placed in a closed space? He focused sun light beams with a mirror onto the candle wick (Priestley had no bright source of light and had to rely on the sun). Today, of course, we can use more sophisticated methods to light the candle like focusing light from a flood light through a converging lens or by an electrical spark. So Priestly proved that plants somehow change the composition of the air.

In another celebrated experiment from 1772, Priestley kept a mouse in a jar of air until it collapsed. He found that a mouse kept with a plant would survive. However, we do not recommend to repeat this experiment and hurt innocent animals. (Teacher can describe the experiment and ask students to draw the inference.)

Plants and Light

Jan Ingenhousz took Priestley's work further and demonstrated that it was light that plants needed to make oxygen (oxygen was discovered a few years earlier in 1772 by Carl Wilhelm Scheele). Ingenhousz was mistaken in believing that the oxygen made by plants came from carbon dioxide.

However, Jan Ingenhousz was the first person to show that light is essential to the plant process that "somehow purifies air fouled by candles or animals".

In 1779, Ingenhousz put a plant and a candle into a transparent closed space. He allowed the system to stand in sunlight for two or three days. This ensured that the air inside was pure enough to support a candle flame. But he did not light the candle. Then, he covered the closed space with a black cloth and let it remain covered for several days. When he tried to light the candle it would not light.

Ingenhousz concluded that somehow the plant must have acted in darkness like an animal. It must have breathed, fouling the air. And in order to purify the air, plants need light. (The teacher can describe the experiment and ask students to draw the inference.)

Neeraja Raghavan, Ph.D., is Consultant, Academics and Pedagogy, Azim Premji Foundation, Bangalore. She completed her doctorate in Chemistry from Princeton University, USA. With over ten years' experience in the field of education, she has also been a freelance writer for several years, having written over 70 articles in leading newspapers and magazines. She is also a member of the NCERT Syllabus Review Committee and Textbook Development Committee 2006. She can be contacted at neeraja@azimpremjifoundation.org.

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