Let students ask and investigate:

THE CASE OF A VARIEGATED PLANT

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What if teachers were to provide interesting but also confusing contexts to students? Would it encourage students to ask questions, and do their own investigations? In this article, the authors present an example of how a plant with variegated leaves provoked students to conduct a series of investigations to satisfy their own curiousity about the natural world.

Who asks most of the questions in a classroom - students or the teacher? In many cases, it is the teacher who does most of the questioning. And what kind of questions does a teacher ask? Questions for which the teacher already knows the answers! Students in schools are trained to give these answers, and are assessed for their ability to do so. Even if they do ask questions, students are expected to only ask 'textbook' questions that lie within their school curriculum. Such questions are inauthentic as they do not arise from the inquirer's genuine curiosity to 'know'.

When do people ask authentic questions? When we genuinely need to know about something; or when a gap or conflict arises between what we observe and our existing knowledge schema. We all ask authentic questions in our day-to-day lives, especially when we have a problem to solve. For example, we may ask other people waiting at a bus station if they know which bus you should take to get to the city centre; seeing a large number of policemen on the roads, we may ask ourselves or others around what's going on; when cooking more dal than usual in a pressure cooker, we may ask ourselves how many whistles will be enough to ensure that it is cooked properly. We constantly interact with our surroundings; and ask questions in order to understand, and in some cases, solve problems.

Why, then, do students not ask authentic questions in class? One reason could be that they rarely get a chance to directly interact with the natural world. Instead, students are largely engaged in the passive process of understanding the world indirectly through books and their teachers. Will opportunities

to directly interact with the natural world provoke students to ask authentic questions?

In an attempt to find out, we organized a three-day workshop with a group of eleven Class VII students (ages 11-13) in which we took the students to a garden with a variegated 'bhendi' (*Taliparitiliaceum*) tree (refer Fig. 1). This ornamental shrub has some green leaves, some leaves with asymmetric green and white areas, and some leaves that are completely white.

We know that middle-school science students are familiar with statements like:

- **Plants make their own food by a process called photosynthesis.**
- **Leaves are green because they contain a green pigment (chlorophyll).**
- **Photosynthesis cannot occur without chlorophyll.**

Given these statements, how does a white leaf, which does not appear to have chlorophyll, make its own food? And, if it cannot make its own food, then how does it survive?

This was the question that came to our own minds when we first saw this plant. We had other questions too. Do white leaves have some green pigments? Do white leaves grow at the same rate as green leaves? Do white leaves get their food from green leaves? We have been doing research to investigate how we can teach students science by encouraging them to ask questions and answer them by planning and conducting their own investigations. Thus what we were interested in seeing during the workshop was whether students would ask some of these questions too. And if they did, would they also be able to think of ways to investigate the answers to these questions.

We decided not to say anything - just bring the students near the tree. To our surprise, students in the workshop spontaneously started talking to each other and asking themselves questions about the tree. These questions were on a variety of aspects, including the colours, shapes and sizes of new, old and fallen leaves, thorns, and flowers etc. All their questions were recorded and displayed on a board. Students worked in small groups, discussing ways of investigating these questions. Each group planned and conducted their investigations with minimal help from us.

Figure 1. A variegated Bhendi (Taliparitiliaceum) shrub - about 2.5 metres high. Credits: Gurinder Singh.

In this article we describe different activities that arose from this project. Some of these activities were performed by us prior to the workshop; others were planned and performed by students to answer their own questions. We do not expect these activities to be replicated in the step-by-step manner in which they are described here. Our purpose is to share some examples to show how students used the context of variegated leaves to generate questions and conduct scientific investigations.

Is chlorophyll necessary for plant growth?

An activity which is sometimes done in school in order "to prove that chlorophyll is required for photosynthesis" is to take a variegated leaf, remove its green pigment by dissolving it in alcohol, and show that only the areas which were formerly green test positive for starch. However, this is a rather tedious procedure, and it actually does not prove that chlorophyll is required for photosynthesis, or even that photosynthesis is occurring. It merely indicates that only the green areas contain starch. It may even lead students to ask questions like, "Why does a potato, which is not green - also contain starch?" Is the potato also capable of carrying out photosynthesis? We can also question whether starch is an indicator of photosynthesis.

Figure 2. Compare some of the different kinds of leaves of the variegated Bhendi (*Taliparitii tiliaceum*) shrub. Credits: Karen Haydock.

We found some very simple ways to use variegated leaves to investigate the relationship between the presence of green pigment and food production, assuming that more food will result in more growth. This can be done by asking whether white leaves, or white parts of leaves (as shown, for example, in Fig. 2), have stunted growth.

One hypothesis that we had was that white leaves would be stunted because they contain less chlorophyll, which is essential for photosynthesis to occur. An alternate hypothesis was that the white leaves, or the white parts of leaves, would not be stunted because of a dense network of veins, which could carry food from one part of a leaf to another or from green to white leaves. To investigate these hypotheses the following activities could be useful.

1. Are white leaves smaller than green leaves?

This question can be investigated by selecting representative samples of white and green leaves, and measuring their sizes.

Students can devise various ways of comparing leaf sizes: with or without a scale or using graph paper to measure surface areas (refer Fig. 3). This activity is suitable for students of classes VI to X, and is a good way to integrate science and mathematics. It also motivates students to devise ways to measure the surface area of odd shaped objects.

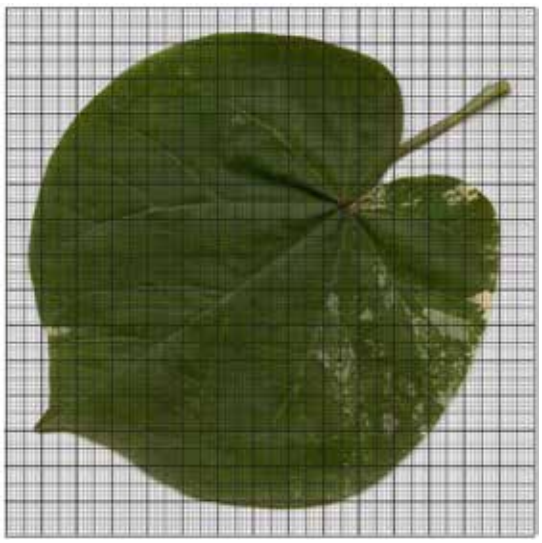

Figure 3. Measuring the surface area of a leaf using a graph paper. Credits: Karen Haydock.

2. Does a plant have fewer white leaves than green leaves?

If the plant being studied is small, it may be possible to count all of its leaves - this is appropriate for middle-school students. The alternative is that students may need to devise some sort of sampling method – an activity that may be a good exercise for students of classes XI and XII. This method will require learning and using some methods of statistics.

The presence of very few mature but many immature white leaves might indicate that green leaves survive better than white leaves.

3. Are the white halves of a leaf smaller than its green halves?

This question can be answered without even plucking any leaves from the plant. Students can simply fold each leaf in half along the midrib, and observe which side is larger (refer Fig. 4).

Figure 4. Comparing the relative size of the white vs. green halves of a variegated leaf. Credits: Karen Haydock.

This is an easy activity, even for students of classes IV or V. We tried this out by testing dozens of leaves of variegated Bhendi and could not find a single leaf in which the half that clearly contained more white was as large as the half which contained more green, suggesting that growth of the white parts of leaves is stunted.

We also noticed that bulges on the margins of variegated leaves corresponded to green areas (refer Fig. 5), supporting the conclusion that the intervening white areas have stunted growth. It would be interesting to see whether these observations hold for other variegated plants too.

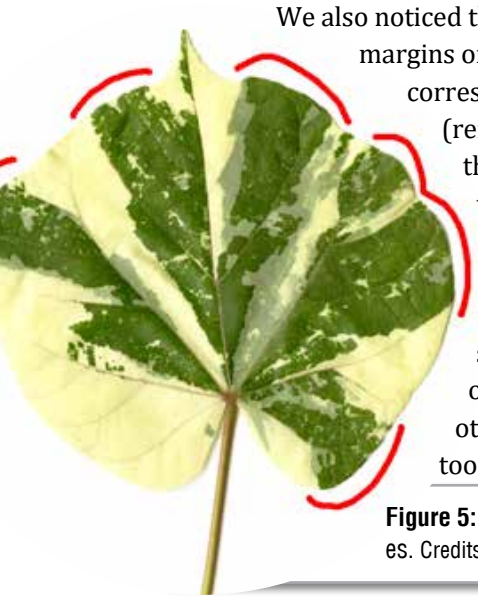

Figure 5: A variegated leaf with bulges. Credits: Karen Haydock.

4. Do white leaves weigh less than green ones?

In order to answer this question, we searched for green and white leaves of the same size (which was slightly difficult), and weighed them on an electronic balance. To our surprise, we found that some green leaves weighed considerably less than a white leaf of the same size. However, after the same leaves were dried, the white ones usually weighed less than the green ones. This indicated that perhaps the white leaves are producing - or at least storing - less food. Or perhaps the green parts produce more cells or more bulk.

5. Are white leaves thinner than green leaves?

This question was investigated by three girls who participated in the workshop (see Fig. 6).

They devised their own method to answer this question, estimating the thickness of leaves by feeling them. Each student would take turns to stand with her eyes closed and both her hands outstretched. Her companions would place a green leaf in one of these outstretched hands, and a white leaf in the other hand. The student with the closed eyes would feel the two leaves and call out the leaf that they thought was thinner. Each girl tested fifteen different pairs of mostly green and mostly white leaves (the same pair of leaves was not tested by more than one person). The three girls recorded the results of this experiment in a table. They reported that white leaves were thinner than green leaves in eleven cases (as they had expected based on their initial observations), and appeared to be of the same thickness in two cases. In another two cases, green leaves appeared to be thinner than white leaves. In one of these cases, they noticed that the green leaf was a lighter (brighter and yellower) shade of green, compared to a thick dark green leaf nearby. It was also much more flimsy. Although it was quite a large leaf, it was probably immature. Based on this investigation, the girls concluded that in general, the white leaves of the Bhendi plant are thinner than the green ones, perhaps because they are not able to make enough food for themselves, and/or do not get enough food from other leaves on the plant.

6. Do white leaves wilt faster than green leaves?

In the same workshop, a group of four 13-year-old boys noticed limp and shriveled white leaves on a branch that had been left overnight in a glass of water. In contrast, green leaves on the same branch had remained 'healthy' (turgid, actually).

Figure 6. Feeling leaves. Credits: Karen Haydock.

The boys therefore hypothesized that white leaves are not as healthy as green leaves, because they cannot make their own food and they rely on food provided by green leaves. They tested this by comparing branches with only green leaves, only white leaves, and mixed green and white leaves. They placed one of each type of branch in water and left it overnight. They also put one of each type in soil and left these overnight, after watering the soil (see Fig. 7). The next day, they were overjoyed to find that the branch of white leaves which they had put in soil had in fact become much limper than the branch of green leaves; while the branch of white and green leaves was somewhere in between these two in appearance (refer images on the left panel of Fig. 8a, b). However, what puzzled them was that they found that the reverse was true of the branches they had put in water (refer images in the right panel of Fig. 8c, d).

Figure 7. Boys putting branches in soil.
Credits: Gurinder Singh.

Figure 8a and 8b: Branches in soil: before and after. Credits: Karen Haydock.

Figure 8c and 8d: Branches in water: before and after. Credits: Karen Haydock.

Resources

For more information on variegated leaves, see the general botany section of the website of the Mildred E Mathias Botanical Garden, based at University of California, Los Angeles, USA: http://tinyurl.com/qgpl6y2.
You can also find out more about variegated plants on the Union County College website: http://tinyurl.com/p2m7vgq.
For a library of images of variegated plant leaves, see: http://tinyurl.com/ojpu9rr.

However, they remembered that two of the bottles had been filled with cold water and the other with water at room temperature. Perhaps this had made a difference? This led to a discussion of variables and the importance of trying to keep all variables controlled except for the one that is being tested. This may be the first scientific experiment that these 13-year-old students had ever conducted themselves, and we were pleased to find they had brought up the problem of the additional variable (cold or warm water) without any prompting from us.

Now it's your turn

What other questions could students explore using Bhendi or other variegated plants? You can try taking students to a garden or a place having a variegated plant and let them explore, talk, discuss, argue, play and experiment, telling them as little as possible, particularly when they start asking questions. They may need some facilitation while planning and conducting investigations.

The beauty of this approach is that you do not need to tell your students what to do, step by step. With limited guidance, even students who have never carried out experiments before can raise their own questions, devise their own methods, carry out and then refine their experiments.

Alternatives to Bhendi

Besides Bhendi, there are a number of other species of ornamental plants that can be used for similar investigations. Some of these are listed below:

Variegated gingko (*Gingko biloba* var.)

Variegated maples (*Acer davidii* Hansu suru, *Acer platanoides* variegatum)

Aralia elata 'Aureovariegata'

Clown fig (*Ficus aspera*)

Some varieties of *Caladium*

Some varieties of *Dracaena*

Some species of *Hosta*.

We obtained slightly different results in similar investigations with other variegated plant species. This makes our conclusions all the more interesting: perhaps not all variegated leaves show obviously stunted growth in white areas?

We hope this article inspires you to let your students raise their own authentic questions and answer them by conducting their own investigations!

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