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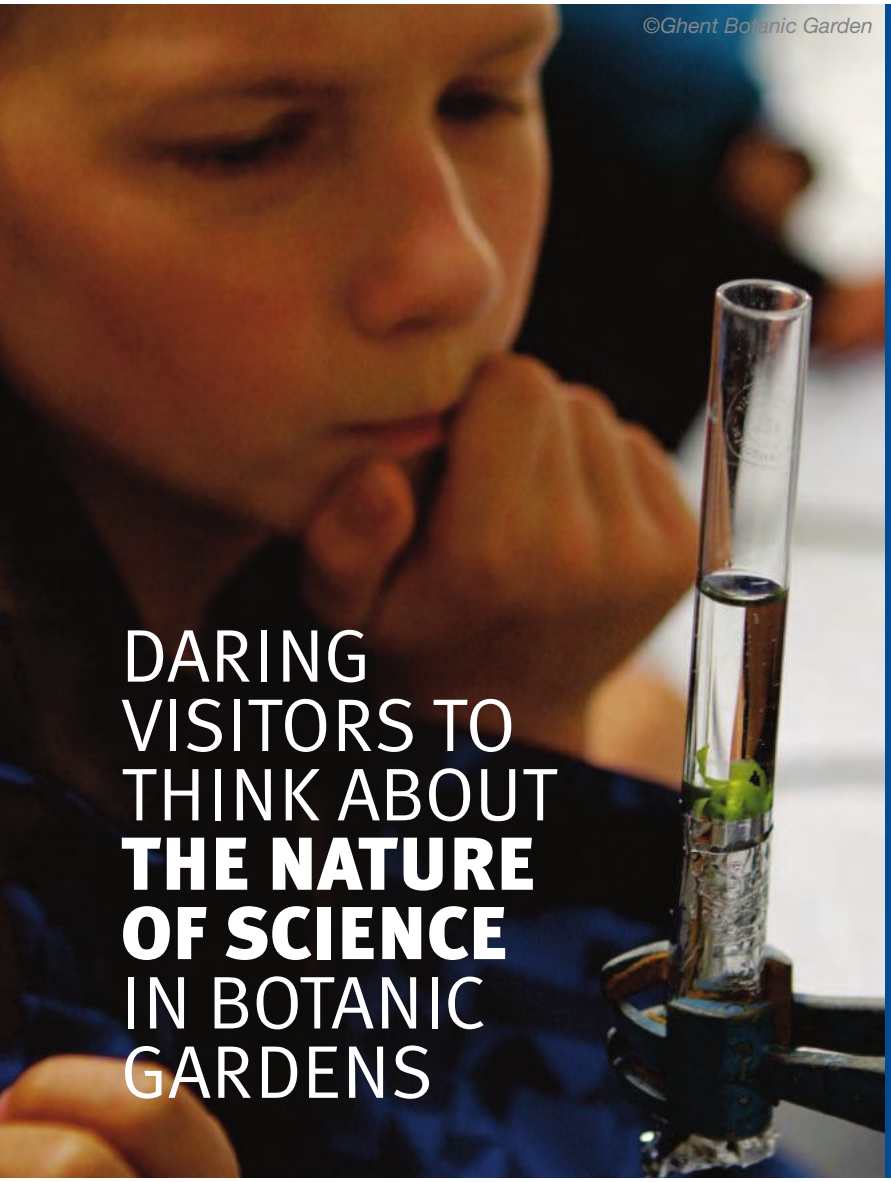

DARING VISITORS TO THINK ABOUT **THE NATURE OF SCIENCE** IN BOTANIC GARDENS

We live in a world in which personal choices and public discussions rely on scientific understanding. To make decisions we need to evaluate scientific evidence, understand how this knowledge was generated and how reliable it is. As botanic gardens are situated at the crossroads of scientific research and education, they provide excellent opportunities to teach about the phenomenon of science itself. Through the use of thought-provoking questions and by stimulating dialogue and reflection, botanic gardens can drive visiting students to think about both the science of nature and the nature of science.

MISCONCEPTIONS ABOUT SCIENCE

Although the classification of plants is constantly refined and scientists are continuously developing new theories, the public and primary and high school students, in particular, can wrongfully assume the domain of science to be a collection of unquestionable facts. Students often harbour a range of misconceptions about the scientific process, the role of the scientist and the value of scientific claims. For example, they may believe that 'a scientist always knows the truth', 'scientific ideas never change', or 'a scientist is not creative' (Schwartz & Crawford, 2004).

To tackle these misconceptions, students need to understand the phenomenon of science itself: a method to obtain reliable knowledge with its own pitfalls and opportunities, with its own rules, regulations, successes and inconsistencies. In other words, students should be familiar with 'the nature of science'. This entails a focus on the scientist as a member of a community who uses empirical data to develop (creative) scientific ideas. It also requires an understanding that, as scientists continue testing and challenging previous interpretations, scientific answers are seldom final (Lederman & Abd-El-Khalick, 2002).

Our aim is to transform eyes-on or hands-on programs into minds-on activities where students – as well as looking and doing - are motivated to think and talk about their observations and science itself.

Many students wrongfully consider the domain of science as a collection of unquestionable facts.

↑ *Children engage in a discussion after doing an experiment ©Ghent Botanic Garden*

DIALOGUE IN THE BOTANIC GARDEN

In the botanic garden of the Ghent University Museum we are currently adapting and expanding the education program to allow students to increase their understanding of the nature of science. Our main focus is on 9 to 16 year olds. We aim to transform our "eyes-on" or "hands-on" program into "minds-on" activities where students – as well as looking and doing - are motivated to think and talk about their observations and about science itself. Since dialogue and questioning increase thinking, educators play a key role in asking appropriate questions (Clough, 1997). We explored three complementary approaches that aim to stimulate thought about the nature of science:

(1) Thinking by doing. Inquiry-based activities allow students to explore, study and experiment. For instance, students study the process of photosynthesis by performing simple experiments with water plants. These activities allow educators to stimulate reflection; questions such as: 'If you saw it once, are you sure that it will happen next time?', 'how can a scientist know whether what they think is true?' can stimulate students to think about the scientific process itself, rather than simply the results of the experiment. When students present their findings, questions such as 'Do you just think so or do you know it?' elicit them to think about the value of their findings. Though this approach seeds doubt in the students' minds, it allows the students to connect with the uncertainties accompanying scientific investigation, uncertainties that only further investigation may sooth.

(2) Thinking by stepping into the shoes of a (historical) scientist. By taking the scientist's perspective, students are motivated to think as a scientist. With regards to photosynthesis, for example, students can re-enact the historic experiments of Van Helmont, Priestley and Sachs. Step by step, these experiments reveal the central nutrients of plant metabolism and the changing theories about photosynthesis that have been formulated throughout history. By experiencing the different steps necessary to come to our current understanding, participants realize that scientific truths of today may also change in the future. More immersive drama activities further allow children to experience the world of science. Children can explore the glasshouses as if they are historic plant hunters stunned by the diversity of plants and eager to describe and discern patterns in the Flora. A dialogue with the children about how to classify the variety of plants can help them to explore the relevance and principles underlying the ever changing classification systems.

"The only consistent characteristic of scientific knowledge across the disciplines is that scientific knowledge itself is open to revision in light of new evidence."
NGSS Lead States (2013)

↑ *In a philosophical dialogue an educator facilitates a group conversation by asking questions to encourage debate and inquiry ©Sanne Bijnens*

↑ *Can a rabbit be a scientist?' Big questions can spark philosophical dialogue about the characteristics a scientist should have ©Ruth Van Wichelen*

(3) Thinking by participating in a philosophical dialogue about science. Questions such as: 'What is the difference between a scientist and a magician?', 'Can a rabbit be a scientist?' or 'Can we ever really know how plants evolved?' may sound funny at first, but they can spark an inquiry into what makes science science or a scientist a scientist. A philosophical dialogue aims to elicit the critical reflection of the participants. The educator plays a key role in facilitating the dialogue by asking for explanations and arguments through questions such as: 'why do you think so?', 'What do you mean by the word…?', 'Can you give an example?', 'Is there someone who disagrees?', why?', 'Are you contradicting yourself?' The educator takes what is known as the Socratic stance. This means that they do not intervene with regard to the content of the discussion, but only facilitate the dialogue, thus enabling freedom of speech and thought for the students (Lipman, 1991; Schjelderup, 2009).

FINDINGS AND CHALLENGES

While we were experimenting with the different approaches, we observed that a mix of both hands-on inquiry activities and minds-on challenges can motivate a broad range of students to participate in the dialogue and reach rewarding conclusions. For example, one of our 14-year old participants answered *"Most ideas change, but some remain the same for a long time. We will never know for sure whether what we know is absolutely correct"*.

Our educators reported that it is not easy to ask the right questions and stimulate the thinking process; that it takes time to acquire 'the Socratic stance' to questioning. Therefore, we found a training program was helpful. Once the questioning attitude is honed, however, educators report that it deeply influences their way of interacting with students. It becomes easier to ask appropriate questions and is easier to motivate children to get involved with activities in the garden.

In short, once the educator gets the knack of it, a dialogic approach motivates students to investigate, explore and think for themselves. In this way, we can turn botanic gardens into spaces to think and talk between the plants and to wonder about both the nature of science and the science of nature.

A dialogic approach motivates students to investigate, explore and think for themselves.

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← *Children explore the greenhouses of the botanic garden as if they were plant hunters in tropical forests ©Ghent Botanic Garden*