Roots

Botanic Gardens Conservation International Education Review

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Pollination and botanic gardens

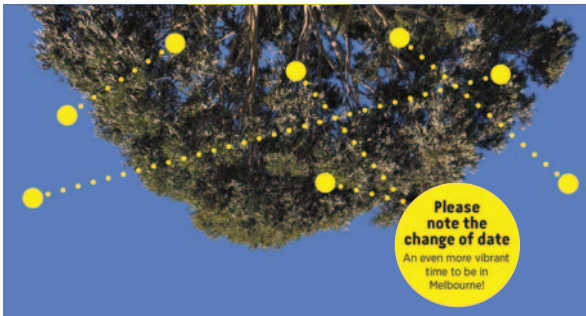
BOTANIC GARDENS CONSERVATION INTERNATIONAL

Contribute to the next issue of Roots

The next issue of Roots is all about education and technology. As this issue goes to press, most botanic gardens around the world are being impacted by the spread of the coronavirus Covid-19. With many gardens closed to the public, and remote working being required, educators are having to find new and innovative ways of connecting with visitors. Technology is playing an ever increasing role in the way that we develop and deliver education within botanic gardens, making this an important time to share new ideas and tools with the community. Have you developed a new and innovative way of engaging your visitors through technology? Are you using technology to engage a wider audience with the work of your garden?

We are currently looking for a variety of contributions including articles, education resources and a profile of an inspirational garden staff member.

To contribute, please send a 100 word abstract to **helen.miller@bgci.org** by 15th June 2020.



INFLUENCE & ACTION

Botanic Gardens as Agents of Change

Due to the global impacts of COVID-19, BGCI's 7th Global Botanic Gardens Congress is being moved to the Australian spring. Join us in Melbourne, **27 September** to **1 October 2021**, the perfect time to visit Victoria.

Influence and Action: Botanic Gardens as Agents of Change will explore how botanic gardens can play a greater role in shaping our future. With the accelerated loss of biodiversity across the globe, increased urbanisation, population growth and climate change, our need to work together to find new solutions for the future has never been greater.

Join inspiring speakers, fascinating workshops, panel discussions, and symposia, in addition to a specially curated evening cultural program focusing closely on Australian aboriginal culture and the vibrant contemporary creative and food scenes for which Melbourne is globally renowned. With a focus on influencing the future, for the first time in the history of the Congress, 7GBGC will deliver a Youth Program for future Gardens' leaders aged 18-24 – young people actively involved in horticulture, ecology, environmental and conservation science, and land management.

ROYAL BOTANIC GARDENS VICTORIA · VICTORIA State Government · bganz · BOTANIC GARDENS CONSERVATION INTERNATIONAL · BGCI 7th Global Botanic Gardens Congress

For more information visit:
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Forthcoming Issue
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Cover Photo: A young boy participating in the pollination themed photo booth at Pollinator Days 2019, VanDusen Botanical Garden (Lorelei Martell)

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Further details available from:

- Botanic Gardens Conservation International, Descanso House, 199 Kew Road, Richmond, Surrey TW9 3BW UK. Tel: +44 (0)20 8332 5953, www.bgci.org
  BGCI Europe: Suzanne Sharrock, Email: suzanne.sharrock@bgci.org
  BGCI Southeast Asia and Oceana: Joachim Gratzfeld, Email: joachim.gratzfeld@bgci.org
  BGCI Latin America: Noelia Álvarez de Róman, Email: noelia.alvarez@bgci.org
- BGCI(US) Inc, The Huntington Library, Art Collections and Botanical Gardens, 1151 Oxford Rd, San Marino, CA 91108, USA. Tel: +1 626-405-2100, E-mail: usa@bgci.org Internet: www.bgci.org/usa
- BGCI-China, South China Botanical Garden, 1190 Tian Yuan Road, Guangzhou, 510520, China. Tel: +86 20 85231992, Email: xiangying.wen@bgci.org, Internet: www.bgci.org/china
- BGCI-Africa, Kirsty Shaw, BGCI Africa Office, IUCN Eastern and Southern Africa Regional Office (ESARO), P.O. Box 68200 - 00200, Nairobi, Kenya, Tel. +254 (0)725295632 Skype: bgci_kirsty, Email: kirsty.shaw@bgci.org, Internet: www.bgci.org
- BGCI-Russia, c/o Main Botanical Gardens, Botanicheskaya st., 4, Moscow 127276, Russia. Tel: +7 (095) 219 6160 / 5377, Fax: +7 (095) 218 0525, E-mail: seed@aha.ru, www.bgci.ru

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Helen Miller

FIRST WORD
POLLINATION AND BOTANIC GARDENS

This issue of Roots is all about pollinators and the fascinating and complex relationship between a plant species and its pollinator. It is estimated that around 87% of all flowering plant species are pollinated by animals (Ollerton *et al* 2011), the majority (around 20,000 species) are bees, but this also includes a variety of insects, as well as birds, mammals and even reptiles (WWF 2018). Animal pollination also plays a key role in food production – with crops pollinated or partially pollinated by animals accounting for around 35% of global food production (Kleijn *et al* 2009).

Unfortunately, many of our pollinators are currently suffering declines due to land use changes, land management, pesticides, disease, invasive species, and climate change. Pollination is therefore an important story to engage botanic garden visitors with. It is also an extremely accessible subject that can be used to draw visitors in, adult and child alike, to the wonderful world of plants.

Pollination is a key topic for botanic gardens but the challenge, as with any topic, is to find new and innovative ways to explore it. On page 26, you can read about the University of Vienna Botanic Garden's approach, which uses large scale fabaceae models to teach students about pollination and coevolution. At the University of Alberta Botanical Garden (page 29), pollination is taught through play, with students acting as either bees or flowers in a large interactive outdoor game, to gain a better understanding of what is really happening when pollinators visit flowers. At VanDusen Botanical Garden, an annual field trip festival integrates art, science, maths and active movement to showcase the exciting world of pollination (page 13). And in our resources spotlight (page 43), the Royal Botanic Garden of Madrid and partners, have developed a new app called Pollinizapp. This is an educational game that allows players to experience what it is like to be a pollinator, visiting flowers and collecting pollen.

Our partner, PlantSnap, have an augmented reality feature in the PlantSnap phone app that identifies a flower in need of pollination and uses augmented reality to show a bee pollinating the flower followed with an explanation of why pollination is important. Read more about this and other resources on page 44.

Opportunities to learn about and identify pollinator species are also a great way to enthuse visitors about plants and their pollinators. As part of an annual 'Plants, insects and honey' festival, the University of Warsaw Botanic Garden have developed a quasi-citizen science survey called Insect Observer, where visitors have the opportunity to experience being a scientist and identify pollinators in the garden, read more about it on page 17. At the Fairy Lake Botanical Garden (page 39), as part of a series of pollinator programmes and activities, they have developed a butterfly booklet, that promotes the high butterfly diversity in and around the garden, and encourages visitors to take part in a butterfly survey to collect data and learn more about pollination and pollinators.

Pollination is an extremely accessible subject that can be used to draw visitors in, adult and child alike, to the wonderful world of plants.

↑ *Education Program Coordinator Ping Honzay, The University of Minnesota Landscape Arboretum, with a honeycomb.*

Pollination is a key topic for botanic gardens but the challenge, as with any topic, is to find new and innovative ways to explore it.

In an increasingly fragmented and urbanised society, highlighting the importance of green spaces and wild habitats for pollinators is essential. At the Rotterdam Zoological & Botanical Gardens, they have created a new flower field at the entrance to the gardens to attract native pollinators and showcase the need for wild spaces such as this to their visitors. Read more on page 32.

At the University of Minnesota Landscape Arboretum, they are exploring conventional farming practices, pollinators, and the role of integrated pest management practice to maintain plant and pollinator health. You can read about this on page 35.

I'm also pleased to see that a number of the articles focus on projects that aim to highlight the range of pollinator species that plants rely on. The honey bee is often seen as the poster boy for pollination, and the focus of much of what we see or read about pollinators. But the reality is that pollinator species are hugely diverse and almost all are suffering similar population declines.

At the Royal Botanic Gardens, Kew, the story of honey bees told through *The Hive* exhibition is now being expanded to include other insect species through a new pollination trail that is opening this year, read more about it on page 6. At Meise Botanic Garden (page 9), a discovery tour has been developed that takes visitors on a sensory pollination safari to experience the wild pollinators of plant species kept in the garden's Plant Palace greenhouse (including sunbird and bat pollinated plants). At Phipps Conservatory and Botanical Gardens, their summer of pollinators celebration will put a spotlight on Pennsylvania's native pollinator species (page 20). And at the Harold Porter National Botanical Garden in South Africa, a new pollinator programme will include a bird, bee and butterfly themed garden with new interpretation that showcases different pollinator species, the threats they face, and how we can help (page 23).

However, what this collection of articles also shows, is that there are still opportunities to tell new stories about pollination. Firstly, to highlight biodiversity decline and how we can help our native pollinators, but also to bring those often forgotten pollinators such as birds and bats, centre stage.

At the time of writing this article, I am, like many of you working at home due to the Covid-19 pandemic that is having such a devastating effect around the world. Bats, as the likely host of the original virus are currently experiencing a lot of unwarranted negative press that threatens their conservation. But bats are of course also important pollinators and seed dispersers with some crops and rare plant species reliant almost exclusively on bats for pollination. Bat pollination occurs in approximately 250 plant genera and includes examples such as, tequila, which is derived from *Agave tequilana, Ceiba pentandra*, an important source of fibre worldwide, economically important fruits such as *Durio zibethinus* and wild relatives of the domestic banana. In addition, in highly fragmented tropical habitats, nectar bats play an important role in maintaining the genetic continuity of plant populations and thus have considerable conservation value (Fleming *et al* 2009). Perhaps there is a role then, for botanic gardens in sharing stories about the vital role that non-insect pollinators such as bats also play, for both ecosystem health and plant conservation.

This is another jam-packed issue, which demonstrates the importance of this topic to botanic garden education but also showcases the hugely varied and engaging activities that have been developed to invite visitors into the world of pollination. Enjoy!

↑ *Bat pollination ©Daniel Hargreaves*

Unfortunately, many of our pollinators are currently suffering declines due to land use changes, land management, pesticides, disease, invasive species and climate change.

↑ *Melitta heamorrhoidalis. ©N. Godijn*

Authors: Harriet Stigner and Patrick Walsh

EXPANDING ON THE HIVE: PROGRESSING THE POLLINATION STORY

The Hive is a multimedia art installation that has stood at Royal Botanic Gardens, Kew (Kew) since 2016. During this time, it has helped visitors to understand the importance of honeybees and the power of pollination. Four years on from its installation, Kew is embarking on the next phase of the pollination conversation. Through the collaboration of horticulturalists, designers, and scientists, Kew is celebrating the myriad of lesser-known pollinators that underpin and sustain the diverse plant life on earth. The pollination trail opens spring 2020.

THE HIVE

In June 2016, Wolfgang Buttress brought a multimedia art installation called *The Hive* to Kew. Standing at an impressive 50-feet tall, *The Hive* immerses visitors in a stimulating multi-sensory interpretation of a honeybee hive. With the help of signage and docents, *The Hive* has elevated the national dialogue about the plight of the honeybees. Since its installation, around 6 million visitors have passed through Kew's gates. News stories about *The Hive* have reached a much wider audience of 354,918,214 people world-wide.

Buttress' *The Hive* has sparked multiple conversations about pollination, allowing visitors to experience communication between the honeybees through bone conductors which transmit vibrations through visitors' teeth and bones, mimicking the way in which honeybees vibrate messages to each other through their honeycomb.

Talks from pollination experts held beneath *The Hive*, and the opportunity to engage with a team of specially trained Hive Explainers were used to hook visitors' interest in the plight of pollinators through the posterchild of pollination – the honeybee. Honeybees are just one in around 20,000 species of bees worldwide, and bees are not the only creatures that help plants to reproduce.

↑ *An ashy mining bee (Andrena cineraria) emerging from its underground nest site. ©Hauke Koch*
↖ *The Hive at night. ©RBG Kew*

← *A pied hoverfly (Scaeva pyrastri) relaxing on a Passiflora caerulea flower. ©Andrew McRobb/ RBG Kew*

Even outside of Kew, media coverage of pollinators has historically focused on honeybees. A 2016 survey of Australian media reporting found that media outlets put a disproportionate focus on European honeybees as the most important pollinators. Furthermore, they found that only 17% of pollination-related articles mentioned non-bee pollinators.

The Hive's focus on the honeybee has been hugely effective at communicating their vital role in pollination. The Pollination Trail will ensure that the thousands of other insects and animals that pollinate our crops and flowers are not overshadowed. Solitary bees, birds, bats, and even some reptiles all carry out vital pollination services, although we hear less of their stories.

KEW'S RESEARCH

In the same year that *The Hive* was installed, Kew appointed Hauke Koch as the *Ann Sowerby Fellow in Pollinator Health*. Together with the Surrey bee expert David Baldock, Hauke has identified 107 different species of bees within Kew's garden. Hauke's work has highlighted the need to expand our pollination stories and build on the interest and momentum generated by *The Hive*.

Hauke commented that, "At Kew, there is an incredible amount of bee diversity. To our knowledge, Kew is the most bee diverse non-heathland site in the whole of the UK. We can use this exciting news as an opportunity to raise awareness about the huge variety of pollinators that plants depend on to survive." To address the chronic lack of pollinator awareness, Kew's new Pollination Trail celebrates the stories of lesser-known pollinators. By showcasing a broader diversity of insects, mammals, birds, reptiles and wind pollination stories, we can begin to build a more complete picture of the multiple ways that plants are pollinated.

"There are many different types of solitary bee in the UK, and one of the most diverse groups are mining bees. Mining bees (from the family Andrenidae) choose to make their nests in the ground, usually in sunny patches of bare soil. As bee diverse as Kew is, botanic gardens aren't famous for promoting patches of bare soil, for understandable reasons! The opportunity to provide a dedicated area where these bees are encouraged to dwell will provide exciting opportunities for us to extend our research to include this important group of pollinators."
Dr. Hauke Koch

↑ *Matilda Smith's 1891 Illustration of the titan arum (Amorphophallus titanum) which is pollinated by flies and beetles. ©RBG Kew*

THE POLLINATION TRAIL

The new trail builds on the stories and familiar concepts from *The Hive*, expanding to include other bee species. In the Kitchen Garden, for example, stories about how tomatoes and aubergines are buzz pollinated by bumblebees sit comfortably in this space next to stories about how many millions of pounds the UK apple industry alone would lose if not for pollinators.

Our native pollinators face many threats, including loss of food plants, pesticides, climate change, and diseases. Against the latter threat, Hauke, in collaboration with Prof. Phil Stevenson at Kew and Prof. Mark Brown at Royal Holloway University of London, recently found a possible answer to help our bees: nectar of some plants like heather (*Calluna vulgaris*) contains chemicals that help honeybees fight off parasites.

Like Buttress' *The Hive*, which shared real data from Kew's honeybee hive with Professor Martin Bencsik at Nottingham Trent University, the new Pollination Trail aims not only to highlight the work of Kew scientists but to provide new opportunities to support their research.

A new 'insect hotel' will be installed a stone's throw away from Kew's existing honeybee hives and bumblebee boxes. The hotel, created by award winning designer John Little, is built specifically to support mining bees and will hopefully generate valuable data regarding the habits of these little-studied bees.

"There are many different types of solitary bee in the UK, and one of the most diverse groups are mining bees," says Hauke. "Mining bees (from the family Andrenidae) choose to make their nests in the ground, usually in sunny patches of bare soil. As bee diverse as Kew is, botanic gardens aren't famous for promoting patches of bare soil, for understandable reasons! The opportunity to provide a dedicated area where these bees are encouraged to dwell will provide exciting opportunities for us to extend our research to include this important group of pollinators."

Bees aren't the only pollinators that the Pollination Trail will focus on. The neighbouring Rock Garden has been identified by Hauke as an ideal location for visitors to spot rare bee species and hoverflies. Signage in these areas is conveniently located near to the Waterlily Pond, where visitors will be introduced to the idea that beetles are believed to be among the first pollinating insects. Further along the trail, the Grass Garden provides an ideal opportunity for us to show visitors that plants aren't always pollinated by creatures, but sometimes by wind. By making connections between plants and pollinators, we hope to bring visitor's appreciation of plants and our biodiverse ecosystems, to life.

Like *The Hive*, the Pollination Trail is a multi-sensory experience. Whether heightening the visitor's awareness to the percussion of wind in the grass garden, the uplifting aroma of English roses, or the briefly overwhelming stench of the Titan arum (*Amorphophallus titanum*), visitors will be encouraged to notice a plant's distinctive characteristics, and appreciate the adaptations they have evolved to ensure pollination.

For many of us, the word 'pollinator' is often synonymous with the word 'honeybee'. While there can be no doubt that honeybees have been a fantastic way to start the conversation around pollination, we will now give lesser-known pollinators, their time in the sun.

The pollination trail will be open from Spring 2020, visit Kew.org for more information.

↑ *A photo of all the bee species you can find at Kew – about 107 in total estate. ©Hauke Koch*

"At Kew, there is an incredible amount of bee diversity. To our knowledge, Kew is the most bee diverse non-heathland site in the whole of the UK. We can use this exciting news as an opportunity to raise awareness about the huge variety of pollinators that plants depend on to survive."
Dr. Hauke Koch

↑ *Hauke Koch, the Ann Sowerby Fellow in Pollinator Health. ©RBG Kew*

AUTHORS

Harriet Stigner and
h.stigner@kew.org

Patrick Walsh
p.walsh@kew.org

Royal Botanic Gardens, Kew
Richmond, TW9 3DS

Authors: Jutta Kleber and Peter Roels

SEDUCTION AND DECEPTION
DISCOVERING THE SECRETS OF EXOTIC POLLINATION IN THE PLANT PALACE

Meise Botanic Gardens' Glasshouses offer a wonderful playground to discover multiple examples of plants that attract exotic pollinators. From the sunbird pollinated *Strelitzia* to the bat pollinated baobab … they're all there. We designed a discovery tour that takes our visitors on a pollination safari. They discover several pollination syndromes, enjoy interactive moments and even play a 'mating game', during which each participant becomes a flower or a pollinator and has to find his or her 'match'. Fun guaranteed! This guided tour addresses a public of adults looking for deep-learning experiences and explores interactive, inquiry, sensory based, and social-learning methods.

The 'Plant Palace' – the public Glasshouse of Meise Botanic Garden – shows a collection of approximately 10,000 plants, which come from a broad range of climate zones. The Mediterranean zone, the desert, the savannah, the monsoon, and subtropical forests are all well presented. Plants of the tropical rainforest receive special attention, with a focus on palms, epiphytes, African rainforest plants, economical tropical plants, and the flora of the secondary rainforest. Not forgetting the magical collection of tropical wetland plants, where the Giant Waterlily steals the show.
With this enormously diverse collection at hand, an idea grew, to design a guided tour about plant-pollinator interactions, with an emphasis on exotic plants and pollinators.

↑ *Exploring the flower model. ©Meise Botanic Garden*

"Attractive colours, seducing forms, sweet nectar and pertinent smells: we were skilfully introduced to tropical flower seducing techniques."
Lieve, a participant

← *Secrets of the Strelitzia flower.*
©Meise Botanic Garden

'WEEK OF THE BEE': THE RIGHT TIME!

In 2018, Meise Botanic Garden had the honour of hosting the official opening of the 'Week of the Bee' (in Dutch: Week van de Bij), an annual campaign held in Flanders to promote the importance of pollination to the public. Our education staff considered this the ideal occasion to launch the new guided tour, named 'Seduction and deception – secrets of pollination in the Plant Palace'. It was our intention to offer our visitors a high-level informative walk with lots of interactive moments and … a naughty twist.

TARGET AUDIENCE

The tour fits into a series of activities that our Garden offers to what we call the 'added-value seekers' (in Dutch: meerwaardezoekers). These are individuals who are usually beyond the 'first acquaintance level', i.e. they have visited the Garden several times and are seeking in-depth learning experiences. They might be looking for knowledge or skills they can use in their professional life (e.g. teachers), but more often they want to learn for the sake of learning, for personal enrichment and enjoyment. In the terminology of John Falk's Visitor Models, they fit either in the category of the 'Professional/hobbyist' or 'Explorer' (Falk, 2009).

CONTENT AND STRUCTURE OF THE ACTIVITY

As we wanted our visitors to have a profound understanding of pollination, we start the tour with a didactical conversation on the structure and biological function of the flower, using a giant plastic flower model. Through this activity, our guides find out more about the participants prerequisite knowledge, and discover and fill knowledge gaps where needed.

Next, we introduce in a non-theoretical, sensory way, the concept 'pollination syndrome'. This concept is defined as 'a suite of flower traits, including rewards, associated with the attraction and utilisation of a specific group of animals as pollinators' (Fenster et al., 2004). Even though this concept was criticized as an oversimplification of the reality of pollination systems, we believe that it has a didactic value, noticing that 'an observer with no prior knowledge of a particular flower's visitors can make an intelligent guess as to the likely pollinators …' (Willmer, 2011). Through a number of activities, we encourage our participants to have hands-, nose-, eyes-, and tongue-on experiences with flower traits and to link them with specific pollination vectors.

To wrap up the whole activity, we play a 'mating game'. In this game, half of the group of participants become pollinators, the other half become flowers. Both groups receive a picture of their species and some additional pollination related information. By looking at each other's pictures and asking closed-ended questions, one at a time, the pollinators try to find 'their' flowers. The game goes on until all pollinators have found their flowers.

"Amazing to see how the bird of paradise flower unfolds itself as a landing place for perching birds. Technology at top level!"
Peter, a participant

↑ *A pollinator's view of flowers.*
©Meise Botanic Garden

"Explorers: Visitors who are curiosity-driven with a generic interest in the content of the museum. They expect to find something that will grab their attention and fuel their learning."
John Falke in 'Understanding museum visitors' motivations and learning

← *Experiencing flowers with all senses. ©Meise Botanic Garden*

SELECTING THE PLANT SPECIES

Examples of exotic flowering plants that would fit in different syndromes were ample in our Glasshouses. We didn't want to overwhelm our visitors and therefore chose to concentrate on 8 types of plant-pollinator interactions, each explained with one specific example. Furthermore, attention was paid to pollination by humans, with pollination of vanilla as an example. We also explained how and why our Glasshouses gardeners hand-pollinate plants like T*heobroma cacao, Victoria amazonica, Strongylodon macrobotrys* and certain species of our *Coffea* collection. We realised that the success of the sensory approach was largely based on the availability of flowering plants of each type. Therefore, we compiled, with the help of our volunteers, a list of alternatives for each of the selected plants. This would help our guides to find examples of flowers fitting in each of the selected pollination syndromes through the year.

LEARNING WITH MIND, SENSES AND THROUGH SOCIAL INTERACTIONS

Plant-pollination interactions and pollination syndromes aren't always easy to understand. As we aimed for a deep understanding of the topic, we included the following types of activities:

- **Sensory (tasting):** To illustrate the fact that different pollinators have different preferences for sugar concentrations in nectar, we let the participants undergo a sensory experience, by tasting 'nectar' (a sugar solution) of different concentrations and asked them to guess the concentrations.

- **Inquiry based:** We showed the participants a picture of male and female individuals of *Eulampis juglaris*. These hummingbirds show a pronounced sexual dimorphism – the males having a much shorter beak then the females - and let them formulate a hypothetical answer to the question: why do the females pollinate different plants to the males?

- **Sensory/inquiry based:** We provided the visitors with a list of characteristics (colour, form, smell, flowering time…) of a typical 'hummingbird flower', and then sent them on a 'hummingbird nectar gathering' tour through the Glasshouses.

Some interesting plants and their pollinators

1. Heliconia bihai, pollinated by the hummingbird *Eulampis jugularis*.
2. *Musa balbisiana*, pollinated by bats.
3. *Victoria amazonica*, pollinated by beetles
4. *Aristolochia gigantea*, pollinated by carrion flies
5. *Theobroma cacao*, pollinated by flies and midgets
6. *Angraecum sesquipedale*, pollinated by the long tongued '*Xanthopan morganii praedicta*' moth.
7. *Strelitzia reginae* pollination by perching birds.

"Every plant has its own story. This allows you to learn something new in every unique glasshouse!"
Tim, a participant

↑ *Nectar tastes so sweet! ©Meise Botanic Garden*

- **A game to wrap up the activity.** In this game, several important aspects of (informal) learning are applied:

  - On the cognitive level, it addresses a higher level of understanding. All through the tour, participants are encouraged to not only obtain knowledge (e.g. hummingbirds pollinate flowers in the rainforest of South America), but also to obtain a deeper understanding of the principles of the relationship between plant and pollinator. By the end of the tour, they are challenged to APPLY the obtained knowledge, making new combinations of plant species and pollinators.
  - Furthermore, the game is a moment of evaluation. It gives the guide the opportunity to check whether or not the participants grasped the basics of the concept of 'pollination syndrome', and to overcome misconceptions.
  - Finally, the game stimulates learning by social interaction. It stimulates the participants to discuss amongst themselves. Social interaction plays an important role in learning. Interacting with other people has proven to be quite effective in assisting the learner to organise their thoughts, reflect on their understanding, and find gaps in their reasoning (Okita, 2012).

SOME REFLECTIONS

The approach we chose for this guided tour is quite different from the usual adult guided tours organised in our Garden. We noticed that in some cases, guides don't really feel comfortable with 'playing games' or 'sipping nectar' during activities with adults. From the participants side, it surprised us that, even though they appreciated the fun aspect, they were also hesitant and shy when looking for their 'pollination partner' in the game. It would be interesting to find out how we can help our guides to overcome their uneasiness, and, even more important, to find out whether the diffidence of the participants is related to their uncertainty about the content of the game, or rather to the fact that they are – contrary to our young learners – not used to playing didactical games in public.

↑ *Nectar tastes so sweet! ©Meise Botanic Garden*

"Professional/Hobbyists: Visitors who feel a close tie between the museum content and their professional or hobbyist passions. Their visits are typically motivated by a desire to satisfy a specific content-related objective."
John Falke in 'Understanding museum visitors' motivations and learning

↑ *Giant water lily and Aristolochia gigantea (Brazilian dutchman's pipe or giant pelican flower). ©Meise Botanic Garden*

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AUTHORS

Meise Botanic Garden

www.plantentuinmeise.be
Info@plantentuinmeise.be
Jutta.kleber@plantentuinmeise.be
Peter.roels@plantentuinmeise.be

Authors: Hailey Moran and Gillian Drake

POLLINATOR DAYS AT VANDUSEN BOTANICAL GARDEN

Spring in Vancouver, Canada, is vibrant, colourful, and ideal for the Vancouver Botanical Gardens Association (VBGA) to host *Pollinator Days* at VanDusen Botanical Garden. A field trip festival for elementary students that takes place over three action-packed days, this buzz-worthy event conveys the importance of pollinators in relation to plants, people, and place through hands-on activities that encourage playful exploration and learning. Using an interdisciplinary perspective, the diverse and beautiful environment of the Garden, and the additional expertise of community partners, this event has had immense success in engaging students across Metro Vancouver.

VanDusen Botanical Garden is a 55-acre oasis in the middle of Canada's third largest city, Vancouver. The sprawling Garden provides a space for quiet contemplation, collective community, and an array of educational opportunities for people of all ages. Part of the success of *Pollinator Days* can be attributed to the use of this incredible location where children can explore thousands of blooming flowers and encounter a wide range of pollinators. Engaging in place-based learning has great potential for inspiring passion in the 900 students and adults attending (Gray & Birrell, 2015). During *Pollinator Days*, children roam the Garden discovering secret paths, honeybee hives, the ever-popular maze, and pollination-themed activity stations. The event sparks curiosity in local ecology and promotes active learning through its informal layout allowing groups to balance the day between structured activities and self-guided exploration of the Garden. The combination of formal and informal learning allows students to thrive on a field trip that aims to be fun as well as foster environmental literacy.

↑ *The interactive Pollen Pals exhibit set up in the Perennial Garden just before the students arrive for Pollinator Days 2019. ©Lorelei Martell*

"I loved it! One of the best field trips I've been on. It connected really well to what we were studying and I loved the variety of the workshops. I wish we could've gotten to them all"
Teacher, Pollinator Days 2019

Pollinator Days uses interdisciplinary and interactive activities to communicate the importance of pollinators in our lives, for the ecosystems around us, and for our food systems. Our microscopes-to-murals mindset allows us to develop inspiring activities that engage young students in the intriguing and intricate world of pollination. By integrating art, science, math, and active movement into pollination-themed activities, we encourage students' engagement in the science of pollinators while developing knowledge, insights, and passion around the topic (Gray & Birrell, 2015). Interdisciplinary education also helps promote critical thinking and problem-solving skills, providing students with multiple lenses through which to tackle a topic or issue (Humes, 2013).

One of the annual favourite stations at *Pollinator Days* is See Like a Bee, which explores how bees see light in the ultraviolet spectrum. This station helps students visualize the abstract concept through comparisons of how humans and bees see the same flower. Using ultraviolet paint, the students create nectar guides on an image of a flower which, under a blacklight, allows them to see like a bee! This successful station incorporates science, art and experiential learning to impact youths' experience and their understanding of pollinators. Active movement is also essential to ensure students fulfill their sense of exploration. *Picky Pollinators*, an activity where students race to match pollinators to their preferred flower, demonstrates this. This station, run by a partner organization, is filled with laughter and panting children for the duration of the festival and its popularity can be attributed to the balance of education and movement.

← *VBGA Education staff finding pollen to show students in the Garden at Pollinator Days 2018. ©VBGA*

↑ *Two young students who really dressed up for the occasion on Pollinator Days 2017. ©VBGA*

"Your program was an amazing extension of our learning this year! As we ride back on the bus right now I'm hearing amazing chatter of their experiences today! Going to get more classes at my school on board for next year!"
Grade One Teacher, Pollinator Days 2019

"Fabulous way to teach kids about nature and the importance of bees"
Teacher, Pollinator Days 2019

← *Students looking for the Queen bee within an observational hive. ©Lorelei Martell*

Pollinator Days is unquestionably enhanced by community collaboration with partner organizations whose goals and values align with those of the VBGA. Our partners host activity stations in their specialist field, together working to achieve our collective goal of bringing the world of pollinators to life. Our longtime partner, the Environmental Youth Alliance, brings bee specimens to view under microscopes. Combined with the pollen collected in the Garden, this station gives students the opportunity to get up close and personal with pollen and pollinators. In 2019, we partnered with the Formation and Design Program at Langara College to create an interactive and educational exhibition, *Pollen Pals*. Students in this design program put their creativity and learning to the test with the challenge of creating a durable outdoor exhibit that would inspire and endure a large number of elementary aged children. *Pollen Pals* made its debut at Pollinator Days and did not disappoint.

Pollen Pals was effective in that it explored multiple species of pollinators. The VBGA is conscious of the honeybee bias that exists in the world and how this bias often manifests as a hyper-focus on honeybees, which can result in other native pollinators being overshadowed (Farrah, 2018). In British Columbia, it is estimated that there are around 500 species of native bees that are critically important to supplying ecosystem services such as the mason bee (EYA, 2017). Visually different to the classic image of a bee, the mason bee is more reminiscent of a fly - often metallic green or blue. This small native bee is extremely effective at moving pollen throughout an ecosystem (Minter, 2019). Using *Pollinator Days* to inform students about a diversity of pollinator species helps to form a new generation of citizens who have an understanding of the importance of local native pollinators that require more conservation, funding, and attention (Requier *et al*., 2019)

↑ *VanDusen Botanical Garden's on-site honeybee hives being maintained by community partner, the Main Street Honey Shoppe. ©VBGA*

↑ *Students learning how bees see different wavelengths of light at our See Like a Bee station. ©VBGA*

As *Pollinator Days* has continued to innovate and expand, exciting new opportunities have arisen. In 2019, we were the site of a research study conducted by the Entomological Lab from Simon Fraser University. The study explored bumblebee nest preferences and elements of the experiment could be seen throughout the Garden which proved a wonderful resource during *Pollinator Days*. Three of the scientists conducting the research attended the festival and engaged with the attending students. These scientists were professional young women; as a result, we hope they inspired young girls to become involved in STEM careers. Highlighting green careers is a new focus at Pollinator Days, which will be expanded in 2020. The *2020 Garden Trend Report* highlights the growth of such opportunities, predicting that jobs in horticulture will outnumber graduates two to one (Garden Media, 2019). Horticulture, environmental communication, green research, agriculture, and many more jobs are popping up within urban communities. Demonstrating these careers to students of all ages may encourage them to consider environmental careers.

Pollinator Days strives to inspire the next generation of environmental leaders by providing youth with tools to understand the environment, the importance of pollinators in their lives, the ecosystems around them, and invoke a sense of fun and excitement in learning about nature and its complexities. By using an interdisciplinary perspective, place-based learning, and experiential activities, we have the power to instill a deeper admiration for the natural world in the students who attend (Gray & Birrell, 2015). As we look to the future we hope to expand *Pollinator Days* with new Garden features such as a Bug Hotel, a Teaching Garden, and diversify our connections with our organizational partners. Most importantly we hope to engage and inspire more youth each year as we continue to grow plant-based literacy within our community.

↑ *Students sampling locally produced honey at the Honey Taste Test station. ©Lorelei Martell*

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AUTHORS

Hailey Moran
Community Outreach Coordinator
VanDusen Botanical Gardens
hmoran@vandusen.org
vandusengarden.org

Gillian Drake
Contributing Author:
Director of Education
VanDusen Botanical Garden
gdrake@vandusen.org
vandusengarden.org

Authors: Anna Albin and Krystyna Jędrzejewska-Szmek

SCIENCE FOR THE WHOLE FAMILY
THE INSECT OBSERVER GAME

How do you distinguish a hoverfly from a common fly or a bee? Why does environmental monitoring need to be systematic? How do you fill in a research form? All these questions are answered during the Insect Observer game, played annually by non-researchers at the University of Warsaw Botanic Garden (UWBG). Participants go through the whole scientific process: they learn to identify pollinator groups, to collect data, and later see the overall results posted by UWBG staff on social media. They learn about the importance of pollinators, find out that insects are not that scary, and that science can be fun.

"Learning by doing" is not only a saying. Different studies show that hands-on experience is invaluable in the learning process and also a major factor in developing awareness of conservation and the environment (e.g. Stohr-Hunt 1996, McKinley *et al*. 2017). This is why, at the University of Warsaw Botanic Garden, we put an emphasis on high quality, engaging educational activities. One example is Insect Observer a quasi-citizen science game played annually during a summer festival, where anyone can experience what it is like to be a scientist and to study pollinators. As pollination is one of the main research topics at the University of Warsaw Botanic Garden, participants' experiences are also closely related to the research activities that are undertaken at this institution.

↑ *Participants become familiar with different feeding strategies by looking at insects' magnified mouthparts. ©Aga Skorupka*

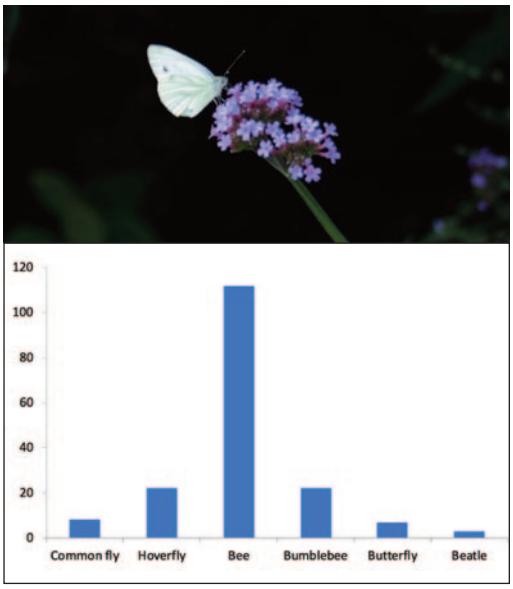
We believe that at times when science is often considered detached from everyday life, being able to show that research and nature can be fun is of great importance.

"Plants, Insects and Honey" is a two-day educational festival for families. For the past 12 years, it has been taking place in late summer. The main attractions include garden walks, various workshops, and a thematic fair – all highlighting the role of pollinators in the environment. The Insect Observer game has been a big part of the festival since the beginning. During all 12 annual events, it has attracted more than 1000 observer teams. Each year we see familiar faces, as well as new visitors, excited to become researchers, even if it is just for one hour.

The rules are as follows: first, the participants, mainly families, are given a brief lesson on how to identify different pollinator groups: beetles, butterflies, bumblebees, bees, hoverflies, and common flies. Preserved insects from old entomological collections and stereoscopic microscopes serve as teaching aids. Next, the participants are instructed that at each plant marked on the map they need to observe and count pollinators for a total of three minutes and complete the research form accordingly. Each year a few currently flowering plants are chosen for the observations. To show the variety of pollinators' preferences and strategies the flowers chosen highlight different flower structures and colours. In 2019 they were: Himalayan balsam *(Impatiens glandulifera*), Argentinian vervain (*Verbena bonariensis*), Chinese chives (*Allium ramosum*), Common ivy (*Hedera helix*), and Old man's beard (*Clematis vitalba*). Participants receive an Observer's set: this includes a map with marked plants, a form, and instructions. There is no time limit for the task; we only ask that they return the completed forms when they leave the Garden. Our researchers, along with the education team, analyse the forms and post the results with interpretation onto the Garden's Facebook page or, previously, on the website. The posts are always written in an informal and easy to understand way, illustrated by graphs and pictures.

← *One of the observer teams discussing who is going to fill-in the research form. ©Aga Skorupka*

↑ *Bees were the most commonly seen insect in the 2019 event. ©Krystyna Jędrzejewska-Szmek*



↑ *An example of how results are presented to the public on Facebook. Here data from 2019 for Argentinian vervain is shown. ©Krystyna Jędrzejewska-Szmek*

← *Learning to identify hoverflies is a new skill for most participants. ©Iza Kuzyszyn*

This year, during two days in early September, 51 research teams observed 1734 pollinators across the five plants chosen. From the results posted on the Garden's Facebook page the next day, one of the things people were able to learn about was the insects' flower-choice preferences. For example, that flies were attracted to ivy, because they can easily feed on the very accessible nectar in its open flowers with their relatively short mouthparts. Bees were the most often recorded insect group and the role \of solitary bees as pollinators was emphasized. Environmentally conscious choices were also discussed. For example, people were encouraged to plant more butterfly-friendly species, like campions (*Silene* sp.) or soapworts (*Saponaria* sp.), as each year there is a downward tendency of recording butterflies – both during the Insect Observer and generally in the city. The importance of planting plants that flower in early spring or late autumn, was also highlighted, so that insects have access to food throughout the season.

Even though data collected during the game have not yet been used in the University's pollinator research (as there are considerations around lack of scientific consistency and potential observers' bias), the activity brings participants closer to the whole scientific process. Visitors learn to identify different pollinator groups (distinguishing hoverflies particularly, is often a new skill) and collect data using principles of scientific robustness. In addition, once collated and analysed, those that take part can see how their data has contributed to the overall results and discussion and learn something new about pollinators such as the food preferences of different insects.

It is well documented that citizen science can have a range of positive outcomes for those taking part, such as: fostering an understanding of science (Trumbull *et al*. 2000) and the environment (McKinley *et al*. 2017), as well as increased awareness of environmental issues (Bonney *et al*. 2009). These are key elements built in to the Insect Observer activity. We believe that at times when science is often considered detached from everyday life, being able to show that research and nature can be fun is of great importance. With so many people experiencing what it is like to be a researcher during the Insect Observer each year, we hope that we are able to show that science is enjoyable and exciting not scary.

↑ Old entomological collections serve as a teaching aid. ©Aga Skorupka

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AUTHORS

University of Warsaw Botanic Garden
Al. Ujazdowskie 4, 00-478 Warsaw, Poland
Contact e-mail: anna.albin@biol.uw.edu.pl

← Learning about pollinators integrates participants not only within but also between teams. ©Aga Skorupka

Author: Ryan C. Gott

POLLINATORS: OUR GARDENS' BEST TEACHERS

At Phipps Conservatory and Botanical Gardens, we strive to create, support, and teach the intricate and delicate connections of the natural world. This year, our three-month Summer of Pollinators celebration will create opportunities for the public to learn about the pollinator-plant partnerships that help bring them food, fiber, and medicine. Pollination is the perfect entry into exploring the incredible ecosystems of which we are a part and encouraging others to view the world through new eyes.

WHY POLLINATORS?

Celebrating pollinators is a natural extension of our work in gardens, conservatories, and arboreta dedicated to plants. Pollinators help between 75% and 95% of all flowering plants reproduce, keeping us in business (Ollerton, Winfree &Tarrant, 2011). These services provided by pollinators also provide nearly $170 billion to the global economy annually (Gallai, *et al*., 2009). Unfortunately these animals that help keep the world running may also be in precipitous decline. In the past few years, insect population decreases garnered media coverage as an "insect apocalypse," even if the extent of the issue and its complicated causes and consequences are still being assessed (Montgomery, *et al*., 2020). To protect and support the pollinators that we so depend upon, we can increase pollinator-friendly spaces and teach others to do the same.

↑ *Dr. Ryan Gott introduces guests to the "Insect Inn" at Phipps. ©Paul g. Wiegman*

"We don't have to figure out everything by ourselves: there are intelligences other than our own, teachers all around us."
Dr. Robin Wall Kimmerer, Braiding Sweetgrass

POLLINATORS AS TEACHERS

Plant-pollinator systems are accessible and relatable gateways into our natural world. From their connections to the food we eat to the natural beauty of a bird or butterfly, pollinators and pollination spark curiosity. Bees and butterflies also tend to be fuzzy and cute, which jumps the hurdles towards affinity that people tend to encounter when thinking about arthropods (Berenbaum, 2017). At Phipps we will give pollinators a platform with our three-month long Summer of Pollinators from June to August 2020.

With honey bees, a non-native species in North America, so often the focus of pollinator news, the Summer of Pollinators will put the spotlight on Pennsylvania-native pollinators through a number of programs, educational tools, and on-site displays. Twelve adult education courses will span topics including insect illustration, basic entomology, and floral arrangement with pollinator-friendly flowers. Activities for children will include all-day pollinator-focused camps, a Play Farmers' Market, and Rooftop Edible Garden highlighting pollinator-dependent food, and Story Time programs to learn and sing about bees, butterflies, and hummingbirds. The whole family will enjoy exploring our pollinator gardens, observing our on-site "Insect Inn" hotel, participating in public programs about wild orchid-pollinator relationships, and attending our yearly BioBlitz Family Fun Festival in which they will be invited to join nature walks, meet researchers, and participate in a biological survey of living species in the surrounding Schenley Park. A pollinator education intern will also be on board this summer as a roaming interpreter in our gardens, encouraging visitors to look closer and think more deeply. And finally, our expert Horticulture team are designing our gardens with new native perennials and research-proven pollinator-friendly annuals to guarantee we will be buzzing with activity all summer. Altogether, the Summer of Pollinators will be an exciting opportunity for the public to meet these plants and animals in a whole new way. We hope the lessons learned from this program can serve as a model for other gardens to pursue their own native pollinator events.

Pollination is a fabulous introduction to the complexities of life. We should listen to the lessons offered by these plants and animals. As Dr. Robin Wall Kimmerer (2013) put it, "We don't have to figure out everything by ourselves: there are intelligences other than our own, teachers all around us." Whether its formal courses, informal activities, community-based science, or other undertakings, opportunities bloom around pollinators and plants (Birkin & Goulson, 2015; Chen and Sun, 2018).

↑ Dr. Maria Wheeler-Dubas helps little sprouts search for new pollinator friends in Phipps' Rooftop Edible Garden. ©Phil Johnson
← A hummingbird and Crocosmia 'Lucifer' are seen in Phipps' Outdoor Garden. ©Paul g. Wiegman

"We need acts of restoration, not only for polluted waters and degraded lands, but also for our relationship to the world."
Dr. Robin Wall Kimmerer, Braiding Sweetgrass

The Play Farmers' Market at Phipps is shown with all the food that is available thanks to pollinators (above) and all that we would lose without pollinators (below). ©Phipps Conservatory and Botanical Gardens

THROUGH THE EYES OF A BEE

Pollinators are a fantastic educational tool and help provision us with so much of our food, but supporting them in gardens has bigger-picture benefits as well. Tending plants that promote pollinators maintains a complete ecosystem that supports all of its associated life. One example is the Carolina chickadee, which only thrives when native plants support an abundance of insects (Narango, Tallamy & Marra, 2017). When you support the base of the ecosystem, the higher levels are that much more stable.

Interacting with and appreciating a healthy ecosystem full of living things has its own physical and psychological benefits as well (Grinde & Patil, 2009). Our desire to connect in this way to nature is referred to as biophilia, or an inherent love of life. I believe the most important aspect of biophilia is what I call "biosonder" (derived from "sonder," or the realization that other humans live and experience their own lives as vividly as you do your own). Biosonder refers to the realization that you are just a small part of a large system, and every other organism in that system has experiences, perspectives, and challenges you will never understand. In other words, biosonder is truly envisioning the world through the eyes of a bee. When you picture the enormity of the world around you in such a way, it is wonderfully humbling. You gain an empathy for all that is around you and treat organisms as neighbors and collaborators, rather than "others." This process is restorative, and as Dr. R. W. Kimmerer (2013) points out, "We need acts of restoration, not only for polluted waters and degraded lands, but also for our relationship to the world." Pollinators, their plants, and pollination create a wonderful springboard into this way of thinking. Phipps Conservatory is leading people through this jump because, in the end, supporting pollinators is the least we can do in return for the lessons they teach us.

↑ *Sustainable perennial plants in full bloom outside the Phipps Welcome Center supporting a myriad of native pollinator visitors ©Paul g. Wiegman*

← *Campers at Phipps explore flowers and all the animals that associate with them. ©Phil Johnson*

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AUTHOR

Ryan C. Gott
Associate Director of Integrated Pest Management
Phipps Conservatory and Botanical Gardens
Pittsburgh, Pennsylvania
United States of America
E-mail: rgott@phipps.conservatory.org
Website: www.phipps.consveratory.org

Authors: Linette Ferreira and Loretta Floors

POLLINATION UNPACKED

To address the prevailing lack of knowledge amongst people regarding the vital role pollination plays in nature, to ensure food security, and the functioning of healthy ecosystems, the Harold Porter National Botanical Garden in Betty's Bay, South Africa, are planning to launch an innovative pollination project in the near future. Not only would visually attractive, interpretive signage, and focused environmental education programmes highlight the topic, but a theme garden called the Birds, Bees and Butterflies garden is being developed. This would offer a combination of 'indoor classroom' scenarios and a hands-on nature based experience.

Today, in many places, there is still a lack of understanding about pollination; what it is, who does it, and the vital role it plays in keeping all of earth's terrestrial ecosystems healthy, functioning, and surviving. In an attempt to unpack this topic visually and practically to emphasise the important role of pollination in nature and in our lives, the beautiful Harold Porter National Botanical Garden in Betty's Bay, South Africa, are planning to launch an innovative pollination project. In addition to specific interpretation and programmes, this project will also include a new Birds, Bees and Butterflies theme garden. This will complement the existing environmental education community outreach initiatives linked to the national school curriculum. These highly interactive, fun-filled learning programmes will be open to all, this includes learners, youth and community groups, students from higher education institutions, and adults. These programmes would comprise theoretical learning activities as well as field excursions in the garden to unpack the topic in a practical way. This project is an excellent example of the concerted effort that SANBI makes to enhance visitors' knowledge and skills, to assist them to understand the natural world better, and to form a positive, sustainable relationship with the environment.

↑ *Loretta Floors explaining plant adaptation to learners from the Bergkroon Primary School. ©Eunice Jurgens*

There is still a lack of understanding regarding pollination; what it is, who does it, and the vital role it plays in keeping all of earth's terrestrial ecosystems healthy, functioning and surviving.

A PICTURE REALLY IS WORTH A THOUSAND WORDS

Visual communication is a powerful tool to create messages with impact. An image can deliver a powerful message without using a single word and a series of images can tell an entire story. With this in mind a range of visually attractive, eye-catching storyboards have been designed to create greater interest and enthusiasm for the subject, and to reinforce the messages and aspects of pollination we want to convey. They will also provide a window into the environment that many visitors and learners might not be able to experience or witness themselves.

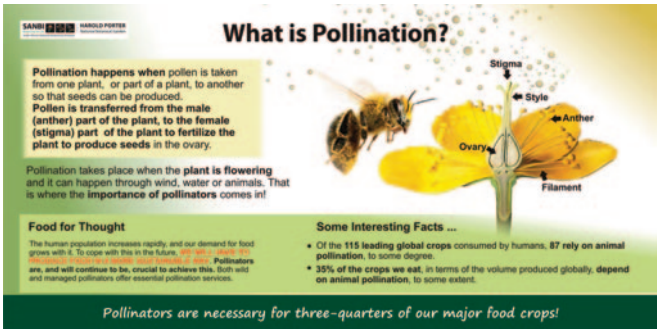
The storyboard, called *Not just bees, but an array of creatures*, highlights the different kinds of pollinators. When people think of pollinators, honey bees often come to mind first. Although they definitely rank among the most important pollinators of food crops, there are an incredibly large range of non-bee pollinators that also do the job very effectively. These include flies, beetles, ants, birds, bats, wasps as well as butterflies and moths. There are also some other unexpected pollinators such as monkeys, lemurs, possums, rodents and lizards known to pollinate some plants. What we often forget, or do not know about, is that humans took over the job of bees to pollinate crops in some parts of the world.

Pollinators in danger emphasises the fact that bee populations are in peril on a global scale and their numbers are declining due to factors that threaten all biodiversity. Without pollinators the very existence of the human race are threatened as over 80 percent of the world's flowering plant species depend on animal pollination to produce the seeds that will become the next generation of plants. We and other animals rely on pollinators to produce the majority of crops that we like to eat, such as nuts, vegetables and fruits; all essential components of a healthy diet. Many crops are also utilised for fibre, fodder, biofuels, timber and herbal medicines. Another dependent on pollinators for reproduction is ornamental plants that are cultivated for decorative purposes. Loss of habitat is the primary reason for the decline in pollinators, followed by improper and indiscriminate use of pesticides. Pollution and invasive species also add to the problem.

↑ *Connecting with nature in the outdoor classroom. Loretta Floors with learners from the Siyabulela Primary School. ©Eunice Jurgens*

↑ *Learners planting a tree ©Eunice Jurgens*

↓ *(Below left) Storyboard depicting what is pollination (Below right) Storyboard about different pollinators (Botttom left) Kinds of pollination highlighted (Botttom right) Pollinators in danger storyboard. ©Linette Ferreira*



← *Ways to create a safe haven. ©Linette Ferreira*

Providing a safe haven depicts practical examples on how to be a game-changer in one's own back yard. It gives options one can apply to create a safe haven for pollinators such as providing bat houses as shelter for bats to encourage these fascinating creatures to make your garden their home. Installing a bee or insect hotel will offer a habitat and much needed nesting site for many insects. Planting endemic, indigenous plants that are well adapted to the specific climate of your area, or by keeping an area in the garden in its natural state can provide a variety of natural food plants for pollinators. A big yes-yes would be refusing or limiting the use of harmful pesticides and fertilizers in your garden and before you know it you might influence the whole neighbourhood to be more pollinator-friendly and what a bonus that would be to pollinators!

THE OUTDOOR CLASSROOM, MORE THAN MEETS THE EYE

Community outreach and raising environmental awareness is one of the primary goals of the Biodiversity Education and Empowerment Centre and Environmental Interpretation sections of SANBI. Apart from other visitors, more than thirty schools and an average of two thousand learners visit the Harold Porter National Botanical Garden every year to take part in various environmental education programmes. Learners from economically disadvantaged communities as well as well-funded private schools take part in these activities and programmes.

The pollination awareness project will therefore, have the perfect platform to launch itself from, and many learners will be given the opportunity to attend lessons, facilitated by experienced environmental education and interpretation officers. The lessons will cover a wide range of pollination aspects such as types of pollinators; factors that influence pollination; methods of pollination; adaptations of plants; benefits of pollination to humans and threats to pollinators. After an indoor classroom session learners will be taken into the garden to be exposed to a fun, action packed, and hands-on experience. This is where they will have the opportunity to interact with nature in a very personal way as they are encouraged to discover the environment through careful observation, recording, and interpretation of data. The garden, situated in the Kogelberg Biosphere Reserve, offers a haven of opportunities for a wide range of lessons about pollination. Research has shown that people perceive, learn and remember best when they can both see, hear and experience events. Making those vital connections in understanding pollination is exactly what is needed to create awareness and understanding.

Although the success of the project will be difficult to gauge, anecdotal evidence seems to indicate that the visual impact of interpretive signage in combination with the learning programmes have greatly enhanced learners' knowledge and appeared to have had a positive impact on their perceptions of the natural world. Exposure and participating in similar environmental awareness projects in the past have often led to schools embarking on various environmental projects, such as establishing indigenous school gardens.

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AUTHORS

Linette Ferreira, Pretoria National Botanical Garden, Pretoria, South Africa
E-mail: L.Ferreira@sanbi.org.za

Loretta Floors, Harold Porter National Botanical Garden, Betty's Bay, South Africa
E-mail: L.Floors@sanbi.org.za

South African National Biodiversity Institute (SANBI), 2 Cussonia Avenue, Brummeria, Pretoria, 0184, South Africa
Private Bag X101, Silverton, 0184, South Africa
Telephone +27 12 843 5000

Authors: Linda Hämmerle, Peter Lampert and Michael Kiehn

← *Manually pulling down the wings-keel complex allows a closer look at the stamens and the style (Figure 1). ©Linda Hämmerle*

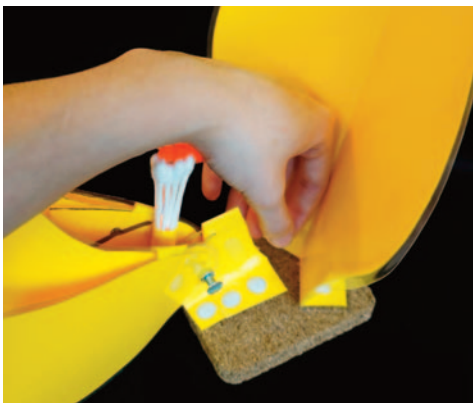
The process of pollination is important to understand plant reproduction. However, pollination often remains invisible for students due to the flowers' small size, which makes it difficult to understand the interactions between flowers and their visitors. Therefore, we have developed a variety of self-made functional flower models of Fabaceae, which visualize the interactions of plants and animals and give students the possibility to experience pollination first-hand. The family of Fabaceae contains various interesting pollination types and illustrates how small evolutionary changes in the structure of the flowers lead to major differences in functionality.

USING FLOWER MODELS OF FABACEAE TO TEACH POLLINATION AND COEVOLUTION

INTRODUCTION

"Plant blindness" describes the phenomenon that people overlook plants and their importance for life on earth (Wandersee & Schussler, 1999, 2001). Moreover, the "lack of movement" in plants leads to a lower interest in plants than in animals (Wandersee, 1986) and to the problem that students even see plants as "less alive" than animals (Yorek *et al*., 2009). This perception is likely to be supported by school textbooks, which focus mainly on plant morphology, but lack descriptions about needs, phenomena or interesting adaptations of plants (Schussler *et al*., 2010).

To increase students' interest in plants it is important to focus on properties which could be interesting for students (Strgar, 2007) and to provide direct experiences with plants (Sanders, 2007; Schussler & Winslow, 2007). Using plants for teaching which affect students' daily lives can support students' interest (Pany & Heidinger, 2015). Also, plant reproduction processes and structures have been shown to be suited to increase students' interests and make plants "liveliness" evident (Stagg & Verde, 2018; Lampert *et al*., 2019).



↑ *"Insect" pushing down the wings-keel complex (Figure 2). ©Linda Hämmerle*

Taking these considerations into account, the plant family Fabaceae offers several advantages for teaching. It contains many species connected to students' daily lives (e.g. Soy bean *Glycine max* or Pea *Pisum sativum*). Consequently, students are familiar with the fruits and seeds typical for the family. The seeds are easily obtainable and plants can be grown in a classroom in a few weeks. The unique shape of the flowers not only allows an easy identification of members of this family, but also builds the basic structure for a broad spectrum of functional adaptations and pollination mechanisms. These pollination mechanisms can surprise students and create curiosity, since they counteract the perception of plants that do not move. In the following section, we present a teaching approach focusing on these mechanisms.

USING FLOWER MODELS OF FABACEAE FLOWERS FOR LEARNING

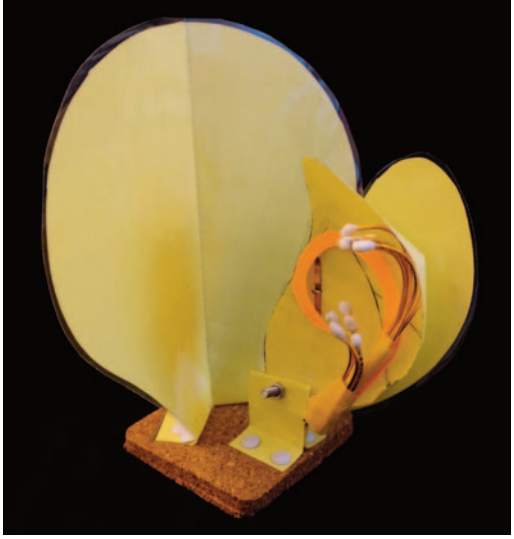
For the following learning session, knowledge about basic flower structures as well as basal knowledge about pollination ecology is recommended. Thus, the session needs to start with a repetition of the basic terms and processes regarding pollination.

General idea of the lesson & design of the flower models
The lessons' centrepieces are self-made flower models of various Fabaceae, which were developed in a scientific project at the Botanical Garden of the University of Vienna. The models are based on other self-made functional flower models used to illustrate pollination in tube shaped flowers and *Salvia* (Lampert, Rose, Kiehn, 2015). In the present setting, students interact with flower models of Fabaceae and experience the four main pollination mechanisms within this family: valvular, brush, piston, and explosive mechanisms.

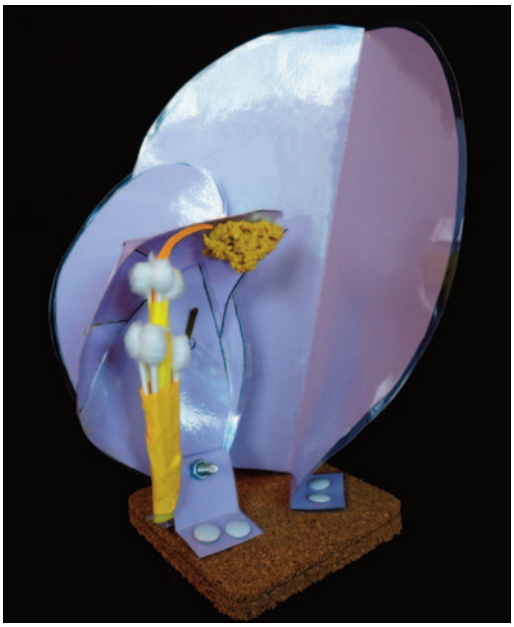
Valvular and brush mechanism are represented by functional models and students can interact with these models and "experience" pollination directly. Piston and explosive mechanism are illustrated by structural models and students can interact with corresponding simplified functional models. All materials used for the models are easily obtainable and building the models is simple. We suggest working with these models in stations, in which students interact with the flower-models.

Working with the flower-models – working in stations
The models for the valvular mechanism and the brush mechanism are prepared in two simple steps: 1) Place "nectar" (= a piece of candy) at the base of the corolla; 2) Put "pollen" (= curcuma powder) on the "stamens" (= cotton buds) or the "pollen brush" (= a chenille wire). To examine the flower, a student's hand acts as the "insect". When the "insect" (= student's hand) tries to reach the "nectar" (the candy), it triggers the mechanism and presses down the wings-keel complex, revealing the formerly hidden stamens and the style (Figure 1 & 2). In the valvular mechanism model, the "insect" touches the "stamens" whereas in the brush type models, the "insect" touches the "pollen brush". In both mechanisms, the "pollen" (curcuma powder) is placed onto the underside of the "pollinator" (the hand).

The structural flower models of the piston and the explosive mechanism showcase the stamens' position inside the closed keel, as one side of the keel and one wing have been removed (Figure 3 & 4). In addition, the piston or "pump" mechanism can be illustrated with a large syringe serving as a simplified functional model: The keel is symbolized by the barrel, the filaments by the plunger. The pollen is depicted by a mixture of curcuma powder, flour and water, which needs to be prepared in advance. By pressing the plunger, the "stamens" press out the "pollen" through a hole in the "keel"-tip (the syringe's hub) (Figure 5).



↑ *Structural model of the explosive mechanism (Figure 3). ©Linda Hämmerle*



↑ *Structural model of the piston mechanism (Figure 4). ©Linda Hämmerle*

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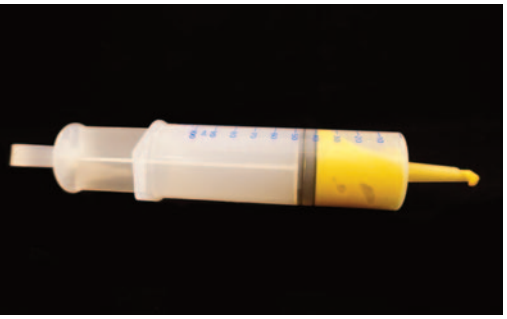

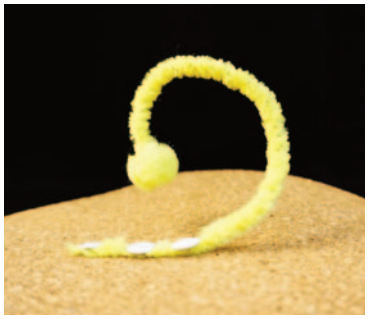

← *Simplified functional model of the piston mechanism (left - Figure 5) and simplified functional model of the explosive mechanism (right - Figure 6). ©Linda Hämmerle*

The functional model for the explosive mechanism consists of a single stamen made from chenille wire that showcases the tensioned position inside the closed keel. The chenille wire must be formed into a curled shape so that holding it flat manually produces tension. When released, the "stamen" snaps forward, hitting the "insect" (the student's hand), releasing all its pollen instantly (Figure 6).

Connected tasks

The students take notes regarding the pollination mechanisms in their working groups. Afterwards, the four mechanisms are compared and discussed in class, especially regarding the flowers' organs. This comparison makes clear that the structural differences between the different pollination-mechanisms are minimal. However, these differences have strong effects on the visitors and make the flowers either attractive or unattractive for potential visitors. The advantages and disadvantages of a narrower range of possible pollinators can be discussed, which leads inevitably to the topic of coevolution.

DISCUSSION

The flower models are an easy and playful way to create student awareness regarding several topics of pollination and evolution. The models can be used both in a classroom setting or to support education at botanical gardens. The models help the understanding of key ideas of structures and functions, which are difficult to observe in the original flowers without prior knowledge. We suggest combining the flower models with observations on original flowers, e.g. *Laburnum anagyroides* (valvular mechanism), *Wisteria sinensis* (brush mechanism), *Lupinus polyphyllus* (piston mechanism) and *Cytisus scoparius* (explosive mechanism). In this way, the models can lead to a profound understanding of the original flowers and their functionality and limits of the models can be discussed.

Furthermore, the presented lesson can be combined with long term observations of growing e. g. peas or soy. These plants can then be pollinated by hand, which leads to additional experiences with the process of pollination. Finally, the development of seeds can be examined. This approach provides experiences with the whole life cycle of a plant and can help students to differentiate between the processes of pollination and seed dispersal, which are often mixed in students' conceptions (Lampert *et al.*, 2019).

To sum up, the presented flower models are suited to create a deep understanding for functional aspects of evolution and illustrate how small changes in the flowers' structure lead to major differences in functionality. Students' experiences with the models can be used to discuss the coevolution of flowers and pollinators. The models also focus on processes and mechanisms, which could improve students' perceptions of plants. The explosive mechanism is especially impressive and contradicts the idea of plants' "lack of movement". Teaching pollination of Fabaceae with the help of functional flower models provides fascinating insights in plant reproduction and evolution.

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AUTHORS

Linda Hämmerle: Research assistant at the Austrian Educational Competence Centre for Biology, University of Vienna (linda.haemmerle@univie.ac.at)

Peter Lampert: Researcher at the Austrian Educational Competence Centre for Biology, University of Vienna; University College of Teacher Education Vienna (peter.lampert@univie.ac.at)

Michael Kiehn: Director of the Botanical Garden of the University of Vienna (michael.kiehn@univie.ac.at)

Author: Jennine L.M. Pedersen

BUZZING AROUND THE GARDEN: EXPLORING POLLINATION THROUGH PLAY

The award-winning Kids in the Garden environmental education program at the University of Alberta Botanic Garden helps bring complex concepts to life through play. In one activity, students act as bees and flowers in a large interactive outdoor game, and gain a better understanding of what is really happening when pollinators visit flowers. This is a part of a garden-wide initiative to increase the public's understanding and appreciation for pollinators.

Good morning! You wake up and feel the sun's warmth on your hive. Yes, that's right, your hive. As one of thousands of bee workers, you have a busy day ahead of you. You'll fly many kilometres and visit thousands of flowers. When you land on those flowers, you'll be coated in a fine pollen as you collect sweet nectar, which you will bring back to your Queen.

Although this is a cute story, most students don't even think about why bees visit flowers and how pollination happens. The Education Department at the University of Alberta Botanic Garden in Canada, set out to help bring this concept to life by having students play a giant game of pollination.

Traditionally, this complex lesson might be taught in a classroom using worksheets and lectures. However, we have found that when we use play as a tool, students are more fully engaged in the learning process, making scientific concepts easier for them to grasp and remember.

↑ *Interpreter dressed as a Queen Bee in the Tropical Plant and Butterfly Showhouse. ©Jennine Pedersen*

Although there are some challenges with this game, there is always the success of students gaining a better understanding of what bees do all day and how they assist flowers with pollination.

In this game, we divide students into two teams: bees and flowers. If assigned to the "bee" team students put on yellow vests with black Velcro stripes and hold a large pipet in their hand. The pipet acts as the bee's proboscis (elongated mouth-part), which they use to suck up sweet nectar from flowers.

If assigned to the flower team, students become either stamens or pistils. "Stamens" get a bucket of Velcro-wrapped "pollen" balls. Students in the "pistil" group receive an empty bucket that represents the flower's "ovary".

Using hula-hoops placed on the ground, we assign one stamen and one pistil into each hoop, along with a container of water that acts as "nectar". The students in the hoops are the "flowers". An empty container placed away from the hula-hoops acts as the "hive".

Bee students fly to a flower and place their proboscis into the nectar. While bees are gathering nectar from the flowers, the stamen students stick their pollen balls onto the sticky parts of the bees' vests. At the same time, pistil students pull different coloured pollen balls off the bees' backs and place them into their ovary bucket. After the bees have been coated in pollen balls from multiple flowers, they run their nectar back to the hive.

To win, the bees must get as much nectar as possible back to their hive, and the flowers must have as many different coloured pollen balls as possible. Having multiple coloured pollen balls represents an increased rate of cross-pollination, which is beneficial to making new seeds and fruit.

At the end of the game, we engage students with questions about pollination. What would happen if there were fewer bees? What if there were fewer flowers? What other pollinators could have been in the game besides bees? How do flowers encourage pollinators to visit them?

↑ Bees and other pollinators love the milkweed (Asclepias speciosa) grown at the Garden. ©Paul Swanson

↓ Inviting families to dress up as their favourite insect during the popular annual Butterfly Day event is just one way the University of Alberta Botanic Garden encourages an appreciation of pollinators from an early age. ©Paul Swanson

← *Staff demonstrate how students play the pollination game. Staff in yellow vest is playing the role of a "bee" bending down to collect "nectar. Staff holding the red "pollen" balls represents the stamen and is sticking them onto the "bee's" vest. Staff holding blue bucket is the pistil and is taking the blue "pollen" off the "bee" and placing it into their "ovary". ©Paul Swanson*

These questions allow students to use what they learned in the game and apply it to the real-world process of pollination. Apart from the mechanics of how pollination works, students learn about the harmonious relationship between bees and flowers, and the adaptation of plants to attract pollinators through colour and smell.

As we designed this game with inexpensive household supplies and tools, one of our main challenges is to fully engage the students' imagination so they believe they are a bee or flower during the game and remember their role. We used yellow vests with horizontal black Velcro to symbolize the stripes of a bee and small balls wrapped in Velcro to symbolize the pollen. In the future, we hope to use more visual costume elements such as dressing the stamen and pistil in costumes. Although there are some challenges with this game, there is always the success of students gaining a better understanding of what bees do all day and how they assist flowers with pollination.

Along with this pollination game, the University of Alberta Botanic Garden has started a garden-wide initiative to engage the public in appreciation of pollinators. For example, costumed interpreters such as a Queen Bee, have been added to the Garden's annual Butterfly Day event. These costumed interpreters not only provide a great photo opportunity, but also tell the public about what it takes to be a pollinator. We are also inspiring an interest in pollination through our Pollinator Garden, and popular children's programming with insect components, like "Pollination Station" and "Going Buggy".

The Education Department at the University of Alberta Botanic Garden strives to provide exceptional and innovative programing to help students connect to the outdoor world. The hope is that after playing this game, the students will know why bees are visiting these flowers, and how important they are for our environment.

↑ *Game supplies, including bee vest (Velcro sewn on yellow vest), pollen balls (Velcro wrapped whiffle balls) and proboscis (large pipet). ©Jennine Pedersen*

↑ *Workers remove honey-capped frames from hives in the Pollinator Garden. ©Paul Swanson*

AUTHOR

Jennine L.M. Pedersen
University of Alberta Botanic Garden
51227 AB-60, Spruce Grove, AB, Canada, T7Y 1C5
(780) 492-3050

Author: Louwerens-Jan Nederlof

CREATING AND MONITORING A FLOWERFIELD FOR WILD POLLINATORS AT ROTTERDAM ZOOLOGICAL & BOTANICAL GARDENS

In the early spring of 2020, Rotterdam Zoological and Botanical Gardens, start the revision of a 320 square metres hard bedded border into a new flower meadow to attract native pollinators like solitary bees, butterflies and other invertebrates. Rotterdam Zoological & Botanical Gardens attracts nearly 1.5 million visitors a year. The planned location to design the new flowerfield is situated directly next to the main entrance of the park. This place is ideal to draw attention to this project, provided with education panels, an 'insect hotel' and of course a wide range of flowers to attract the pollinators. The transition from a "stone surface" into a flower meadow will be part of a monitoring programme to measure results and developments in providing suitable habitats for wild pollinators and invertebrates in an urban enviroment. The results of this short-term monitoring will provide data about wild pollinators and use of the vegetation for other projects in future for interested actors like other zoos and botanical gardens.

PLANNING THE FLOWERFIELD

In February 2019, the first drafts for the development of a flowerfield for wild pollinators and other urban wildlife, appeared as a project when an area near the main entrance of the zoo needed reconstruction. The hard pavement consisting of rocks and stones was cleared up to make space for a flowerfield with herbs, bushes, small trees and a mix of flower seeds to attract bees and other insects over an area of about 320 m^2 situated in a south east direction. As the first Dutch Zoo with BGCI Botanical Garden Accreditation (2019), this project supports the goals; to raise awareness of degraded nature in and around cities and to recreate new areas for vegetation and wildlife. Rotterdam Zoo receives almost 1.5 milion visitors a year. Many of them will see, within a few months, the colourful and attractive flowerfield when arriving at the entrance of the zoo.

↖ *Insect Hotel in our pollinator field. ©H. Kuyten*

Rotterdam Zoo receives almost 1.5 milion visitors a year. Many of them will see, within a few months, the colourful and attractive flowerfield when arriving at the entrance of the zoo.

SELECTING THE PLANTS AND SEEDMIXES

The first design of the flowerfield was to plant out a combination of plants and seeds to attract as many species of pollinators as possible. Therefore we have to keep in mind that several wild pollinators have special habits. According to Peeters *et al* (2002):

a. **Foodplant and nestbuilding specialisations.** Many bees collect pollen and nectar on a limited number of plant species, or use very specific materials to build their nests. The wild bees would not appear without those materials and plant species!
b. **The use of different habitats.** Many bees do not find their food, nesting site, and nesting material at one place in a habitat. They are dependent on many different habitats to do so.
c. **Limited phenological adaptions.** The adult bees of most species appear in more or less the same period of a year and their lifespan is less than a few weeks. They are not able to survive in bad weather conditions without good food resources.

The lack of food during their adult fly period or an unfavourable mowing period of the habitat will cause direct disappearance of the species involved.

Because many common species of wild bees could thrive on a wide range of different flowering plants we selected a list of more than 25 species and varieties with small shrubs and bushes to create variation in flowering period, structure and to provide other needs for the pollinator species, like hiding places and micro-climates. In the early spring a few species of bulbs were added as one of the first nectar plants for early pollinators like bumblebees.

A significant part of the flowering field was covered with a special commercial seed mix of so called 'bee plants' consisting of 50 species of annuals and perennials from a dozen plant families to attract the insects with colour, shape and diversity of flowers over the season.

EDUCATION AND PUBLIC AWARENESS

The botanical department of Rotterdam Zoo has developed several goals for promoting education and publicity awareness of endangered plant species, habitats, and ecosystems. One focus is the opportunity for the public to encourage insect life in their home gardens or balconies. Therefore, an 'Insect hotel' was placed at one of the east-south orientated sites of the pollinator field. The insect hotel was provided by a professional company (www.bijenhotelkopen.nl) who specialise in bee and insect hotels. The wooden construction (260x250x125 cm) is made from wood coming from Dutch natural areas, filled with bamboo cylinders and wooden logs with several drilled holes, creating different nest sizes for wild bees and suitable for their larval development. With information panels situated around the hotel, the public can learn about the occurrence of wild bees in the urban environment, their lifecycle and early development.

↑ *Hard pavement before transition into a flowerfield. ©H. Kuyten*
↖ *Insect Hotel in our pollinator field. ©H. Kuyten*

↑ *Overview of flowerfield before planting. ©R. Doolaard*

↑ *Overview of flowerfield before planting. ©R. Doolaard*

↑ *Planting the bulbs. ©H. Kuyten*

Another way in which the new flowerfield is being used to raise awareness of the importance of pollinators, is by highlighting that the flowerfield is a part of the Honey Highway (www.honeyhighway.nl). This initiative ensures that any new road or railway site is planted with native seed mixes to connect natural areas throughout the city of Rotterdam in a widespread network over the region, using the road sites as the main disperser for wildlife. The botanical department is keen to find out if there are more sites, on the 30-hectare Zoo area, that can connect with this project.

MONITORING

At an early stage in the process, Rotterdam Zoo decided to monitor the flowerfield to collect data about the effectiveness of this project. Does the flowerfield attract wild pollinators? Do they use the flowers from the commercial seedmixes as nectar and pollen sources? Is there any relation between the visitors of the flowerfield and the residents of the insect hotel?

Therefore, we contracted the European Invertebrate Survey foundation (www.eis-nederland.nl) who will carry out three surveys in spring (May-June), mid summer (July) and late summer (end of August- early September). During every visit the observed wild bees, butterflies, hoverflies, Crabronidae and Vespidae will be noted. The situation for 2020 will be considered as the 'zero-situation'.

After two or three years of monitoring, we will have gathered sufficient data to understand the species diversity, the use of the vegetation and the use of the insect hotel. This information will be used to develop guidelines and recommendations for management of the flowerfield in the future.

FUTURE

For the ecological restoration of larger areas in the future, we will use a more natural mix of seeds considering the origin of the natural habitat on site. In the Netherlands there is a discussion about the use of commercial seed mixes, as many bees and other pollinators are not suited to the flowers of exotic varieties and some commercial mixes do not provide food for insects. Commercial seed mixes can be helpful in making a habitat for wild bees and are potentially suitable for smaller areas (like our patch and the Honey Highway), but in larger areas, it is our experience that wild pollinators are less enthusiastic about the strange plant species and flower shapes present.

Acknowledgement:
Gardeners of the botanical department Hans Kuyten and Remi Kroon for their feedback on this article and information about the development and construction of the flowerfield. Jinze Noordijk and Linda Slikboer from EIS for advice and monitoring of the flowerfield and the images of the expected wild bees.

↑ *Commercial seed mixes. ©L.J. Nederlof*

↑ *Megachile ericetorum ©N. Godijn*

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AUTHOR

Louwerens-Jan Nederlof
Botanical Department, Curator of Plants
Royal Rotterdam Zoological & Botanical Gardens, P.O. Box 532, 3000 AM, Rotterdam
The Netherlands, l.nederlof@rotterdamzoo.nl

Author:
Erin K Buchholz

COOPERATIVE HEALTH
USING IPM TO PROTECT POLLINATORS AND FOOD CROPS

The University of Minnesota Landscape Arboretum recently installed agronomic and horticultural crop fields next to our Bee & Pollinator Center, intending to show our visitors conventional farming methods. Conventional farming in the United States is not often associated with pollinator protection, as many pesticides are toxic to bees, butterflies, and other beneficial insects. Focused on the most commonly-grown crops in our region, we will develop and promote an integrated pest management (IPM) program featuring the best cultural, mechanical, biological, and chemical practices to maintain plant and pollinator health.

On September 14, 2019, we welcomed visitors to the Farm at the Arb to discover the past, present, and future of agriculture. Featuring a backdrop of our iconic red barn originally built in 1920, the space has been redeveloped to offer events, tours, and classes on how food is grown.

Adjacent to the Farm is the Tashjian Bee & Pollinator Discovery Center, where interpretive exhibits, an apiary, and a pollinator garden offer insights into honey bees, wild bees, monarch butterflies, and other pollinators. While bee research is primarily conducted on the Saint Paul campus of the University, it was decided that public outreach programs about pollinators are best delivered at the Arboretum in Chanhassen, Minnesota, 40 miles (64 km) west of Saint Paul.

With an annual attendance of around 500,000 people, we are well positioned to introduce horticultural benefits and challenges to a diverse audience. Despite Minnesota's location in the northern heart of farming country, many visitors have never been to a working farm, nor have they seen large-scale agriculture. Fields of wheat, corn, and soy will adjoin fruit trees, vegetable gardens, and herb displays.

↑ *Monarch butterfly on Echinaeca with Arboretum visitor. ©Barb Lindgren*

↑ *A field trip student examines a moth in the garden at the Tashjian Bee & Pollinator Center.*

To prepare for educational programs at the Farm at the Arb, we held a listening session in 2018 to determine what our audience would like to learn from agricultural professionals. Questions involved many aspects of food production, with pest management a main concern. Based on the responses, we believe we can address pollinator protection in the following areas:

- What does crop diagnosis look like?
- What does "pesticide" mean and how does one work?
- What is integrated pest management (IPM), and how do we choose controls?
- Are genetically-modified organisms (GMOs) bad? How do they affect pollinators?
- What is "Precision, Sustainable, or Regenerative Agriculture," and can one protect pollinators better than the others?
- What is the difference between crops certified Organic, or not? Is Organic better for pollinators?

Staff and students will identify the most commonly-seen pest issues specific to food crops in Minnesota. We will explore damage caused by insects, pathogens, and other impediments to plant health. Cultural, mechanical, and biological control methods will be recommended first, as they typically are not considered harmful to beneficial insects. Selected pesticides must be considered non-toxic to pollinators, or be applied when they are not actively foraging - early morning or evening. Additionally, there must be no danger to pollinator health from residue. How can we convey our IPM methods to the public for their knowledge and potential use?

Several organizations share resources to increase pollinator safety. In the USA, the Xerces Society and the University of California offer guidance on preventing bee poisoning through conventional or organic pesticide use. We can identify which pesticides pose little to no risk to beneficial insects, and explain why we might use them.

Horticulture Extension Educators Natalie Hoidal and Annie Klodd conducted a needs assessment of local fruit and vegetable producers in 2019. Growers reported pest management as a top area requiring support. Arboretum staff will coordinate with them to update University Extension information to reflect best management practices for food crops that stress pollinator protection. Extension will review our recommendations, ensuring alignment with current research and peer review, and disseminate them to growers via Extension webpages, newsletters, and workshops.

← *The interior of the red barn includes interpretive signage on the history of Minnesota food crops.*

↑ *Day camp participants marvel at the size and color of a cecropia moth caterpillar (Hyalophora cecropia).*

"As we develop new programming, key areas of interest include the vital role of pollinators in helping us grow food, and how we can successfully manage food crops while protecting these pollinators."
Ping Honzay, Farm at the Arb Education Program Coordinator

↑ *The opening of the Farm at the Arb featured Minnesota-grown sweet corn. ©Susie Hopper*

← *The planned layout of the Farm at the Arb and the Tashjian Bee & Pollinator Center.*

Despite Minnesota's location in the northern heart of farming country, many visitors have never been to a working farm, nor have they seen large-scale agriculture.

Tim Wilson, Farm at the Arb Education Manager, has designed a beginning farmer program for vegetable growers. The Sustainable Horticulture program offers hands-on learning with course content that includes an independent pest project. Students will conduct routine scouting and data collection to determine pest presence, and determine the economic threshold for treatment action. As many of our food crops are pollinator-dependent, students will tailor their farm management goals to include protections for beneficial insects. Buffer strips along fields and cover crops will be selected to provide habitat and nutrition for pollinators.

Programs at the Tashjian Bee & Pollinator Center have stressed the importance of insects since it opened in 2016. Education Program Coordinator Ping Honzay designs, delivers, and oversees workshops, conferences, field trips, and adult education classes, ensuring the Center's message reaches diverse learners. Rather than worry about the negative impact conventional farming could have on the apiary, Ping sees the addition of the Farm at the Arb as a unique opportunity. "As we develop new programming, key areas of interest include the vital role of pollinators in helping us grow food, and how we can successfully manage food crops while protecting these pollinators." As such, her students often thank the bees for the apples they enjoy.

↑ *The red barn is located near our pollinator garden. ©Jason Boudreau Landis*

↑ *Our iconic red barn was built in 1920, and is now ready for visitors. ©RobertEvansImagery.com*

← *Inside the Tashjian Bee & Pollinator Center, visitors can learn about the biology and importance of beneficial insects.*

Through coursework, interaction, and interpretive displays, our students and visitors will be able to:

- Describe how crops look at different life stages
- Recognize cropping systems and stages of field preparation, planting, maintenance, and harvest
- Scout and observe crops for diagnosis
- Identify cultural controls: selecting resistant varieties, soil testing/amendments, crop rotation, and irrigation
- Identify mechanical controls: tillage and mowing, physical removal of impacted plants, lures and traps, and physical barriers
- Identify biological controls: releasing predators to manage harmful insects, and site enhancement for natural pest enemies
- Identify chemical controls that limit harm: beneficial bacterial and fungal pesticides, and conventional or organic pesticides considered nontoxic to pollinators
- Recognize the proper timing of chemical applications to coincide with threshold limits and pollinator activity

Educational objectives are meant not to direct current practices, but engage diverse audiences with science-based practices and inspire a deeper connection with agriculture.

As the Minnesota Landscape Arboretum addresses current and emerging pest issues, we not only wish to be at the forefront of pollinator protection, we want to demonstrate how it can be done.

The partnership between Arboretum & Extension Educators and our Operations staff will enable the Farm at the Arb to promote sustainable agricultural practices beyond the Arboretum with additional field demonstrations and online curriculum. By keeping the lines of communication open through exit surveys and visitor interactions, the public will share a role in conversations about beneficial insects and why they matter. We hope to support a community of practitioners that will develop alongside research and development in conservation science.

↑ *The Tashjian Bee & Pollinator Center is open all year for pollinator-friendly programming. ©Jason Boudreau Landis*

↑ *Education Program Coordinator Ping Honzay examines and maintains the apiary behind the Pollinator Center.*

RESOURCES

- Xerces Society - Reducing Pesticide Use & Impacts. https://xerces.org/pesticides
- University of California - Bee precaution pesticide ratings https://www2.ipm.ucanr.edu/beeprecaution/

AUTHOR

Erin K Buchholz
Integrated Pest Management Specialist
University of Minnesota Landscape Arboretum
buchh006@umn.edu

Authors: Shan Li; Qing Wang; Tao Wang; Weizhe Zhang

← Volunteers teach the students to use the interaction box machine to learn about the pollination process of Cycas debaoensis ©Fairy Lake Botanical Garden Volunteers

VISUALISATION INCREASES THE PUBLIC UNDERSTANDING AND AWARENESS OF POLLINATION IN THE BOTANICAL GARDEN

Pollination involves the transfer of pollen grains to the ovule-bearing organs or to the ovules themselves by different kinds of pollinators. Pollinators are mainly insects like butterflies, moths, beetles, etc. but can be mammals and birds as well. Pollination is a key process for plant reproduction and provides essential ecosystem functions. It is estimated that 87.5% of flowering plants are pollinated by animals, as well as some gymnosperm plants (Ollerton, *et al*., 2011). Pollination has an important role to play in agriculture, economy and business, food safety and human health (Garibaldi, *et al*., 2013; Smith, *et al*., 2015; Hanleya, *et al*., 2015). However, a decline of pollinators in Europe, North America and Australia is well documented (Potts, *et al*., 2011; Ollerton, 2017). In addition, concerns have also been raised about the impact of climate change on pollinator species populations, as well as the process of pollination and plant biodiversity conservation (Kerr , *et al*., 2015; Potts, *et al*., 2016).

Pollination is a complex process and involves many interesting stories between plants and pollinators. These are excellent resources to attract the public's interest but education programmes can often fail if we use abstract word concepts. To explain the complicated pollination process to the public, Fairy Lake Botanical Garden has used various visualization tools including booklets, digital games and cartoons and has considered both angiosperms and gymnosperms. As a result, 75% of the visiting public who used the booklet, acknowledged that their knowledge about pollination had increased and nearly half of people were aware about the importance of conservation for local pollinator species.

↑ The booklet Butterfly – the elf of nature ©Fairy Lake Botanical Garden

↑ *The somatosensory interactive game Tricky Orchid on a big circular screen. ©Jingping Zhang*

The Fairy Lake Botanical Garden have been contributing to this topic through pollinator research projects and educational programmes. This has included a local butterfly and moth identification survey, which was part of an international cooperated research. Compared with the butterfly species in the urban environment of Malaysia and Hong Kong, Shenzhen has a relatively high diversity of butterfly species, considering its city density (Sing, *et al*., 2016). However, due to increasing risks towards pollinators worldwide, it was felt important to develop an early warning project to take action and enhance public understanding of pollinators and ensure we conserve our high-level pollinator biodiversity. Thus, the Center of Service and Education cooperated with the Center of Science Administration at the botanic garden to develop a series of programmes with a pollination theme. The goals of these activities were to:

- Increase pollinator related knowledge amongst the public
- Increase awareness of pollinator conservation amongst the public
- Influence visitor behaviour in activities such as planting nectar rich plants (at the family/community garden level)

We developed two small booklets, two somatosensory interactive games and a cartoon series as part of the pollination project.

The booklets are used to teach basic pollinator information. In 2017, we cooperated with Dr Dong Hui, the deputy head of the Center of Science Administration, to write the booklet *Butterfly – the elf of nature* (Dong, *et al*., 2017). In this booklet, we introduced the body structure of a butterfly, the classification, the local species, the nectar plant list, the Chinese culture of butterflies, the ecosystem and the current conservation of butterflies based on the butterfly species survey (Sing, *et al*., 2016). In this book, we also included an introduction about how to conduct a butterfly count and provided some butterfly species identification guidance. This booklet was used in outreach projects, volunteer training and big butterfly count events. We also produced a simplified version about the butterfly count (with species identification guidance) for volunteers and student team leaders of school clubs organising butterfly count activities.

A picture is worth a thousand words.
Chinese proverb

↑ *Handy version of butterfly booklet ©Shan Li*

The next phase involved the use of somatosensory interactive games to illustrate interesting pollination stories of orchid and cycad species displayed in the exhibition room Renew Project.

In the orchids garden, we used a game called *Tricky Orchid* displayed on a big circular screen (3.7*2.5 meter^2) to show the relationship between *Ophrys speculum* and *Andrena* sp. (mining bees). The orchid plant *Ophrys speculum* uses flower shape and smell to pretend to be a female mining bee, the male mining bee is attracted by the smell during the flowering period. After several trials the male realises that the flowers are not female mining bees and leaves disappointed. However, during this process, pollen is stuck to the visiting insect and is then transferred to a new flower (Stökl, *et al*., 2007; Vignolini, *et al*., 2012). In the game, children stand in the middle of the room, facing the screen and move their hands. The movement of their hands is captured by somatosensory devices and linked to a magic stick, which is shown on the screen. The aim of the game is for the player to move their hands so that the magic stick points to the orchids, and the male *Andrena* sp. is attracted by the open flowers, helping this smart orchid to trick the bee into pollinating the flower for free!

In the cycads exhibition room, an interaction box machine was used to show the pollination process of *Cycas debaoensis*, a rare cycad species in Southwest China. The game was designed by the Center of National Cycad Germplasm Conservation using previous experiment results. In the flowering period, the temperature of the staminate strobilus in the male cycad plant increases and high levels of chemicals are released. This encourages the pollinator, beetles *Erotylidae* sp. to leave the plant and fly to the ovulate strobilus in a female plant. Behind this phenomenon is the movement of pollen between the staminate strobilus and the ovulate strobilus. This machine illustrates this process to young children who are then able to see pictures and get a visual impression of pollination in dioecious plants. In 2019, this cycad pollination story was also told through a 5-minute cartoon. This cartoon was one of the entries in the 2019 Green Leaf Science Douyin short video contest, held by the Botanical Society of China and watched more than 10000 times online.

Pollination stories are fabulous resources to attract public attention. By using good examples to tell the story, we received a lot of interest from the public.

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↓ The cartoon showing the pollination process of cycad plants ©Weizhe Zhang

← Local butterfly identification guidance
©Fairy Lake Botanical Garden

A survey was carried out to look at the impact of the projects on visitors taking part. This survey focused on the impact of the booklet and butterfly exhibition and revealed the following:

- Knowledge - almost three quarters of individuals who used the booklets said that their knowledge of butterflies had increased. In addition, the survey indicated that people who visited the butterfly exhibition rooms had an increased knowledge of pollination.
- Awareness - 43.8% of people who used the booklets were aware that conservation was needed for the local butterfly species. People who visited the butterfly exhibition room, had a positive attitude towards pollination conservation.
- Behaviour change - 20% of volunteers who used the booklets told us that they started to plant nectar plants in their balcony or gardens.

Further surveys to assess the impact of the cycad exhibition room and the cartoon are planned.

Pollination stories are a fabulous resource to attract public attention. By choosing good examples to tell the story through, we received a lot of interest from the public. With additional, knowledge-based programmes such as lectures, training courses, and volunteer monitoring, there is a further opportunity to direct interested individuals into additional Garden roles such as friends, volunteers, school or community project leaders. These people are an important human resource for future pollination projects.

There is still further work to do on the topic of pollination in the Garden. Firstly, the existing activities focused on butterflies and beetles. Other pollinators such as birds and mammals could be the next vital story to tell. Secondly, with a focus on local projects, we used Chinese as the original language for most of the project activities, which reduced the influence at the international level. The next step is to translate the references into English and give more attention to other languages so that our work can be seen by wider audiences.

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AUTHOR

Shan Li
Fairy Lake Botanical Garden, Shenzhen & CAS, 518004
No. 160 Xianhu Road, Luohu District, Shenzhen, China
Email: lishan@szbg.ac.cn

POLINIZAPP

IS A GAME IN APP FORMAT THAT CAN BE DOWNLOADED FOR FREE FROM GOOGLE PLAY (ANDROID) AND APPLE STORE (IOS).

↑ *Polinizapp poster. ©Pelopanton*

Polinizappis an educational game offered by the Royal Botanic Garden of Madrid with the collaboration of the Spanish Foundation for Science and Technology (FECYT). This game, which is available in three languages (Spanish, English and Catalan) simulates pollination in different scenarios. The player is a pollinating insect who needs to contact flowers to get food and to generate seeds. Life (or playing time) is increased by contact with the flowers, since flowers provide pollen and nectar - sources of food. Points are earned only by contact with flowers belonging to their "target species".
To generate one point, the insect has to contact at least two consecutive target flowers of the same species. At the end of the game, these points become seeds, as fertilization of the gametes of the plant will have been performed during the process.

Through the different levels, the player learns about different species of pollinators and plants, and through challenges faced during the game, the player learns about different threats. Threats can take seconds off a life, cause death or the end of the game.

After using this educational tool, teachers (or environmental educators) can follow this up with projects in which students can directly observe pollinating insects and collect data. To this end, the Royal Botanic Gardens has published “SOS Pollinators: Teacher’s & environmental educator’s guide”, a free downloadable activity guide for teachers that provides information about different educational activities that can be implemented in the classroom.

Download the resource from:
http://www.rjb.csic.es/

↑ *Students using the app. ©Clara Vignolo*

Why is the resource useful?
This game is an educational and playful tool for teaching pollination in any educational setting (primary, secondary) or in non-formal education.

Explain how you have used the resource in your practice.
This game has been used mainly in educational establishments, in sessions focused on pollination. It has also been presented in workshops and conferences aimed at teachers.

Do you have any evidence of the impact of the activity? The game has to date been downloaded over 3,500 times.

How can this resource be used by other people? This game is appropriate for pollination teaching at any time of the year in both formal and non-formal education.

↑ *Pollination of a flower. ©Antonello Dellanotte*

AUTHOR

Clara Vignolo
Unidad de Programas Educativos.
Real Jardín Botánico-CSIC
Plaza de Murillo, 2. Madrid E-28014.
SPAIN
c.vignolo@csic.es

RESOURCES

Sustainable Learning – Pollinator resources

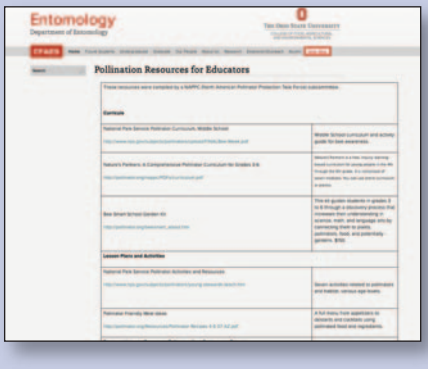
Sustainable Learning aims to connect teachers with free learning resources and expert knowledge to inspire children about sustainability through National Curriculum learning. This includes a series of activities on pollination aimed at ages 5-11.

https://www.sustainablelearning.com/resource/pollinator-resources

The Ohio State University, Department of Entomology - Pollination Resources for Educators

This webpage provides a series of downloadable lesson plans, activities and resources for educators, compiled by a NAPPC (North American Pollinator Protection Task Force) subcommittee.

https://entomology.osu.edu/node/350



Polli:nation toolkit

Polli:Nation was a UK wide initiative supporting pupils from 260 schools to turn their school grounds and other local walk-to spaces into pollinator friendly habitats. The toolkit, produced from this project is a range of resources designed to encourage individuals, schools and organisations to support pollinators.

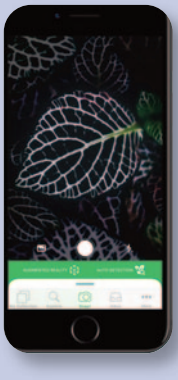
http://polli-nation.co.uk/toolkit-backup/

Pollinator Partnership – education resources

Pollinator Partnership's mission is to promote the health of pollinators, critical to food and ecosystems, through conservation, education, and research. Their learning center provides a range of curriculum lesson plans, educational tools, activities, pollinator facts and links.

https://www.pollinator.org/learning-center/education

PlantSnap



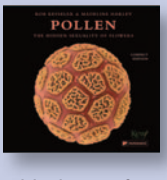
PlantSnap

PlantSnap is a plant identifying app that currently contains over 585,000 species. With users across the globe, the app allows individuals to identify plants from a photo and through doing this is creating the world's largest plant database.
The app also has an augmented reality feature that identifies a flower in need of pollination and uses augmented reality to show a bee pollinating the flower. This is followed by an explanation of why pollination is important.

https://www.plantsnap.com/

PUBLICATIONS

Pollen: The hidden sexuality of flowers – Rob Kesseler & Madeline Harley



This ground-breaking book, now in its fourth edition is the result of the shared fascination of an artist and a scientist with the perfect design of pollen grains. This book provides information on the structure and form of pollen alongside stunning up-close images.

https://papadakis.net/books/pollen-the-hidden-sexuality-of-flowers/

Pollination Power – Heather Angel

Pollination Power offers a unique, truly bird's-eye view of the wonders of pollination at work. In stunning full-colour images, employing the latest photographic techniques.

https://heatherangelphotography.co.uk/pollination-power-book/

BOTANIC GARDENS CONSERVATION INTERNATIONAL

Descanso House, 199 Kew Road,
Richmond, Surrey, TW9 3BW, U.K.

Tel: +44 (0)20 8332 5953
E-mail: info@bgci.org
Internet: www.bgci.org
https://twitter.com/bgci

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