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ABSTRACT
Sustaining a broad diversity of plants is key for a sustainable future. For instance, providing a variety of flowering plants in urban and agricultural landscapes mitigates the current decline of pollinators and biodiversity in general. Therefore, educating about the diversity of flowering plants has high current relevance for biology and environmental education. Unfortunately, students have little knowledge about plant diversity and find botanical topics often uninteresting. Therefore, this paper presents and discusses an engaging teaching approach, where students engage in a role-play with 3D-printed flower models to learn how the morphology of plants affects different insect pollinator groups. To gain insights into students’ experiences with the flower models, guided interviews were conducted one week after this role-play. The interview results show that the students were not only motivated to engage in the role-play, but also gained content knowledge on how the diversity of flowers affects insect pollinators. Hence, the approach highlights how 3D printing can contribute to design teaching approaches that engage students in hands-on activities in order to foster their understanding of flower diversity.

Introduction
Teaching about the biology, relevance, and diversity of plants is an important but challenging task since plants are often marked as ‘boring’ (Elster 2007; Kinchin 1999). One main challenge for educators is the phenomenon of plant blindness which describes how people tend to overlook plants and their importance in their every-day lives (Wandersee and Schussler 1999; Wandersee et al. 2001). This is problematic, because plants are directly linked to key environmental topics such as climate change or biodiversity loss (Pedrera et al. 2021; Thomas, Ougham, and Sanders 2022). As a concrete example, plant blindness can negatively affect efforts in plant conservation, since it receives less funding than animal conservation (Balding and Williams 2016). Therefore, plant blindness can be a potential impediment for achieving sustainable development goals, which makes this issue not only relevant for biology education, but also for policy makers (Amprazis and Papadopoulou 2020).

The reasons for plant blindness are manifold and include innate tendencies, cultural influences and pedagogical aspects (Thomas, Ougham, and Sanders 2022; Wandersee et al. 2001). A limited integration of plant content in school curricula can be one reason that makes it difficult for educators to teach about plants and their diversity to a sufficient extent (Amprazis and...
Papadopoulou 2018). Textbook analyses have revealed that plant content is given less emphasis than animal content (Schussler et al. 2010). Additionally, teachers at school tend to neglect plants in their teaching, which directly connects to insufficiencies in the curricula, textbooks, and science standards (Hershey 2005).

From a conservation perspective, a major challenge associated with plant blindness is that learners have limited knowledge of plant biodiversity and are unfamiliar with common wild plants (Bebbington 2005; Pedrera et al. 2021). A lack of awareness of organisms and their diversity has negative impacts on peoples’ conservation engagement (Breitschopf and Anne Bräthen 2023). The limited knowledge of the diversity of plants can be seen both as a result of, and as a factor reinforcing, plant blindness, since people can only recognise what they already know (Wandersee et al. 2001). Additionally, low levels of knowledge about the diversity of plants are problematic, because they are connected to limited ecological knowledge (Pilgrim et al. 2008). Hence, raising awareness for the diversity of plants and other organisms is highly relevant for biology education.

A greater awareness and appreciation of local flowering plants (e.g. in private gardens) could also contribute to mitigate the current decline of insect pollinators, which is a major global issue (Díaz et al. 2019; Potts et al. 2010; Sánchez-Bayo and Wyckhuys 2019). A lack of flowers in farmland and urban spaces is a core driver in wild bee decline (Goulson et al. 2015). Therefore, scientists highlight that private gardens with a diversity of flowering plants could be key to support insect conservation in urban areas (Gerner and Sargent 2022; Goddard, Dougill, and Benton 2010; Levé, Baudry, and Bessa-Gomes 2019). Engaging in wildlife friendly gardening practices in private gardens would not only support plant and invertebrate biodiversity, but this engagement could also lead to a higher awareness, appreciation and knowledge of the diversity of these organisms (van Heezik, Dickinson, and Freeman 2012). From an educational perspective, these wildlife gardening actions can also contribute to active learning about insect pollinator conservation (Lampert et al. 2023). However, many people do not appreciate ‘unwanted’ flowering plants and tend to ‘weed’ wild flowers from their gardens that would be valuable for pollinators to maintain the ‘aesthetic appeal’ of their gardens (Majewska and Altizer 2020).

Hence, it is important that biology education fosters learners’ awareness, knowledge, and the importance of plant diversity, and how this diversity relates to other organisms. This is in line with the Next Generation Science Standards highlighting the importance of biodiversity and interdependent relationships in ecosystems (NRC 2013). Providing learners with opportunities to experience plant diversity is also crucial to create plant awareness (Stagg and Dillon 2022). For this, educators need teaching approaches that draw attention to interesting aspects of plantlife (Thomas, Ougham, and Sanders 2022). In this paper, we therefore discuss the potential of using 3D-printing as an innovative technology to design engaging educational approaches that enable hands-on experiences with the diversity of flowers.

Teaching about flowers and pollination

The teaching approach and the 3D printing focus on flowers and their structure for three main reasons. First, flowers are the most obvious and diverse features of many flowering plants and key features for children to build up concepts of plants (Bartoszek et al. 2015; Tunnicliffe 2001). The visually attractive bright colours of many flowers break the perceived uniform ‘greenness’ and are therefore more easily noticeable for people (Wandersee et al. 2001). Colourful flowers can potentially increase children’s attention, interest, and retention of information about plants, similar to the effects of colourful fruits (Prokop and Fančovičová 2014). Second, understanding the structure and diversity of flowers has been an important way to comprehend biological phenomena and a key aspect in the history of science in botany. For instance, Linné used it to group plants, and Sprengel used it to understand the principles of insect pollination (Linné 1751; Sprengel 1793). Studying flower structures is still central for plant species identification. Third, comprehending the structure and functioning of flowers is usually a crucial initial step in learning about the life cycle of flowering
plants and sexual reproduction (Helldén 2000). Additionally, connecting the structure and functioning of diverse flower structures provides the basis for learning about co-adaptations and interactions between plants and pollinators. Even small differences (shape, colour, scent, reward) can lead to a different functioning of the flower, e.g. which visitors are attracted or how visitors interact with the flower (Willmer 2011).

Therefore, focusing on the diversity of flowers could be a potential pathway to raise plant awareness and to connect the topics ‘plant reproduction’ and ‘pollinator diversity’. However, understanding the importance of plants and plant reproduction is challenging for learners, as several studies show. Learners have difficulties in understanding the role of the flower in plant reproduction (Helldén 2000) and in interpreting plant reproduction as a cycle (Benkowitz and Lehnert 2009). Additionally, students tend to mix pollination and seed dispersal (Lampert et al. 2020). Generally speaking, students struggle to connect the steps of plant development and reproduction in a correct way (Quinte 2016). Evidently, there is a need for educational approaches that support educators and learners about these issues.

Recent educational studies have shown that innovative approaches to teaching, such as digital flower hunts (Kissi and Dreesmann 2018) and educational theatre (Stagg and Verde 2019), can help improve students’ understanding of flower structure and plant reproduction while increasing motivation. Role-plays using handcrafted flower models have also been suggested as a tool for learning about plant–pollinator interactions (Dreesmann and Kissi 2020; Gubo 2019; Lampert, Rose, and Kiehn 2015). These approaches all engage learners actively and have a high motivational factor.

3D printing technology could be another engaging tool for educating about plant and flower diversity. This technology has great potential for teaching in general as it enhances understanding through visual and tactile elements (Ford and Minshall 2019), supports learning (Liziero and Ivete Basniak 2019), and creates exciting learning experiences (Eldebeck 2021). 3D printing technology creates a 3D object by depositing material (e.g. plastic, ceramic, resin, metal) layer by layer, allowing for the creation of detailed 3D models of flowers.

Using 3D-printed flower models can advance learning about flower structure and diversity as real flowers can be small and difficult to investigate. Through exploring these variations in flower morphology with 3D-printed models, the students can learn that different plant species vary in appearance and differentiate between them. In this way, the flower models can contribute to counteracting limited knowledge about plant species diversity. In addition, these models can highlight how differences in plant morphology are connected to variation in pollinating insects, which connects plant diversity and insect diversity from a more ecological perspective.

3D-printed flower models could therefore be a valuable addition to complement and enhance the work with real objects. 3D-printed flower models can also support the understanding of 2D schematic drawings of flowers found in textbooks. As 3D printers become more common outside of industry and commerce, many schools, universities, and botanical gardens are purchasing them. 3D-printed models are inexpensive to produce and easy to reproduce, unlike traditional purchased models. They can be modelled by teachers or students themselves or downloaded from extensive databases, if available. The advantage is that the models can be individually adapted to the needs of the classroom. In the following section, we present a concrete teaching approach that uses 3D-printed flower models in a role-play to provide students with experiences of pollination and how flower diversity affects pollinators.

**Teaching approach – experiencing the connection between flower and insect diversity**

This teaching approach is based on role-plays, where learners act as insects and interact with handmade flower models (Dreesmann and Kissi 2020; Gubo 2019; Lampert, Rose, and Kiehn 2015), but the approach uses 3D-printed flowers instead. The flowers were modelled with the software
Fusion 360 and printed with a Prusa MK3S+ 3D-printer. The 3D-printed flowers consist of two main parts: a green cup that consists of a calyx tube, the receptacle with the lower parts of the pistil and the stamen; the petals that can be attached by clicking them on to the flowers (see Figure 1). Only a few components of the model (upper parts of the stamen, stylus, stigma) were built from other crafting materials (straws, pipe cleaners) and can be easily attached to the models without glue or tape. This makes the 3D-printed models more flexible, easier to clean, and more durable than prior models.

**Description of the approach**

In the role-play used in this approach, learners act in different insect roles (e.g. honeybees, bumblebees, butterflies). The insects in the role-play receive mouthparts (pipettes) in different lengths (honeybees – short; bumblebees – medium; butterflies – long) (see Figure 2a). The 3D-printed flowers also differ in their calyx-tube length (short, medium, long), representing different real flower types (see Figure 2b). The short flowers represent ‘open’ flowers (e.g. cherry, buttercup), the medium flowers represent flowers with an intermediate calyx or corolla tube (e.g. primroses), and the long flowers represent long tubed flowers (e.g. pinks). The flower models need to be prepared (assemble flower + fill in some water as nectar + put yellow powder (street chalk or curcuma powder) on the stamen as pollen) and then placed in three different places in the classroom according to their tube length.

**Figure 1.** Parts of the 3D-printed flower model.

**Figure 2.** Mouthparts and flower models for the role-play. **Figure 2a:** Pipettes are cut in three different lengths. **Figure 2b:** The three different types of 3D-printed models used for the role-play.
Then the actual role-play can start, where the students receive the task to explore all models and search for nectar in all models, by trying to take up water with their pipettes (see Figure 3). When the insects try to collect the nectar, they get inadvertently in touch with stamens that have pollen on them. Eventually, this pollen is transferred to the stigmas of the flowers when the insects reach into the flowers. After this exploration phase, the students shall go to the flower types, which they would preferably visit in their insect-role. After this role-play, students have the opportunity to discuss their experiences and observations from the activity.

The role-play with the 3D-printed flower models provides hands-on experiences with pollination and insect diversity. It offers several learning possibilities that can be discussed in the classroom after the role-play. In the following, we highlight some predicted outcomes of the role-play and how they link to concrete learning aspects.

- **Learning aspect 1:** *Plant diversity affects potential visitor diversity.* Usually, the ‘insects’ in the role-play assemble at those flowers where the tube length corresponds to the length of their mouthpart. The ‘insects’ choose these flowers based on two factors a) where can they reach the nectar and b) on the level of concurrence, which is lower at models with fewer insect groups.
- **Learning aspect 2:** *Flower visitors are different.* Students can directly experience the differences of the mouthparts. Understanding the differences between flower visitors is crucial to understanding why it is necessary to provide a big variety of plants to support pollinating insects.
- **Learning aspect 3:** *Pollination happens as a side effect of foraging.* The whole activity was about collecting nectar, so students were distracted from ‘pollen’ on the flowers. This ‘pollen’ was transferred during the pollination-game to other flowers as well. This shows that pollination is a side effect of the foraging behaviour and not a deliberate process. The idea that bees actively ‘help’ plants pollinate is a common misconception.

**Implementation and evaluation of the approach**

In this section, we describe how the 3D-printed flower models were integrated in a larger educational design project focusing on insect conservation. The project included several teaching modules covering basic features of insects, insect diversity and their importance, as well as insect decline and conservation action possibilities. Over 200 students from lower secondary schools (grade 7, aged 13–15) from four compulsory schools in a Swedish municipality participated in the
project during the spring of 2022. The flower model activity was part of a teaching module on the importance of insects, which emphasised pollination as a vital ecosystem service provided by insects. The students worked with the flower models for about 30 minutes, including follow up questions (e.g. *How do flowers differ and how can differences in flowers affect flower-visiting insects? How do flower-visiting insects differ and what are the effects on flower visitation and pollination? Why is it important to provide a broad variety of flowers to support pollinating insects?*).

After the first week of teaching, the main researcher conducted guided interviews with a subsample of students (six boys, six girls) from three classes. These interviews were conducted in pairs, leading to six interviews in total. The interviews focused on students’ experiences and their feedback on teaching materials and sequences of the first week of the project. This feedback served as a basis for potential improvements to the teaching materials. The main questions for the students about the teaching materials/sequences were very general: *How did you experience the teaching sequence (here: the flower model activity)? What do you think that you have learnt from this activity (here: the flower model activity)?*

All interviews were recorded and transcribed verbatim. We used thematic analyses (Braun and Clarke 2006) for the analyses of these transcripts using the program NVivo 12 Plus. In this thematic analysis process, the main researcher generated initial codes inductively based on the data. Based on these codes, three main themes were developed: 1) Biological content knowledge; 2) Self-perceived learning benefits; 3) Emotional and physical experiences. In the following section, we report the findings of this analysis. For each theme, we also provide anchor quotes from the interviews to illustrate relevant aspects.

**Results of the evaluation of the approach**

**Theme 1: biological content knowledge**

This theme focuses on students’ responses that referred to the learning of biological content knowledge. The most commonly mentioned aspect by students was that they learnt about *differences of flowers and insects*. This aspect was mentioned in five out of six interviews. Specifically, students learned that different mouthparts enable insects to reach nectar in different flowers. Some students explicitly stated that they were not aware of these aspects before. One student even referred to adaptation processes in this context, although it was unclear whether this referred to a certain behaviour or to a morphological adaptation. The following quotes illustrate these aspects:

‘The biggest thing you learn is that there are different insects for different plants.’ (Student C, male, Interview 2)

‘That they [the insects] have adapted to what is best for them so that all insects can get nectar.’ (Student D, male, Interview 2)

‘That insects are attracted to different colors (…) and that butterflies can access nectar in all flowers, but they mostly go to the ones that have the longest [tubes] because they have the longest proboscis or whatever.’ (Student G, female, Interview 4)

Another aspect of biological content knowledge mentioned in two interviews was that *pollination occurs as a side effect from foraging*. However, one student’s response indicated that the student gained knowledge about the pollination process but confused important terms, such as referring to pollen instead of nectar and seeds instead of pollen.

‘I didn’t know before that they [the insects] pollinated by accident.’ (Student B, male, Interview 1)

‘Well, we learned that when a bee or something like that sucks up pollen, it gets little seeds on it, so when it flies to another flower, it pollinates the other flower.’ (Student L, male, Interview 6)
**Theme 2: self-perceived learning benefits**

This theme covers aspects where students talk about how the flower models influenced their learning and why. On a very general level, in five out of six interviews, students perceived that the flower models supported their learning. The reasons for these perceptions are manifold and included that the activity was perceived as practical, allowed for their own discoveries, and involved movement.

‘It was easier to understand when it was practical, so it was easier to understand and see how it actually is.’ (Student C, male, Interview 2)

‘You learned more, you learned more in the form of finding out something, you get to move and all that, so I will always remember that.’ [Talks about insect diversity afterwards] (Student G, female, Interview 4)

‘I thought it was good because here you learned, it was possible to test this with our [proboscis] (…) so you learned which type is best suited to which, so the butterfly had the longest and then it could go to the longest.’ (Student I, female, Interview 5) (Student L, male, Interview 6)

‘Instead of just sitting still and taking in all the facts, you show the facts yourself.’

**Theme 3: emotional and physical experience**

This final theme summarises whether the flower model activity was perceived positively or negatively and why. We can assume that the students were honest in their reflection, as they gave critical comments to other teaching materials (e.g. parts of worksheets that were perceived as difficult or boring). This theme is also relevant as the flower model activity had an explicit focus on plants, whereas the other sequences had a stronger focus on insects. Hence, this theme addresses the issue that botanical topics are perceived as less interesting (see introduction).

However, all interviewees described the flower model activity as positive. One reason for this perception was the physical interaction with the models, which involved movement and exploration (see also quotes above). In two interviews, the students highlighted that the activity was fun, leading to their positive experience. The students also appreciated the understandability of the approach. Another potential reason is that the students enjoyed the higher activity in comparison to other biology lessons.

‘The teacher didn’t stand and talk the whole lesson, so it was a bit more fun.’ (Student A, male, Interview 1)

‘It [the activity with the flower models] was good.’ [Interviewer asks why it was good] ‘It was easier to understand when it was practical, so it was easier to understand and see how it actually is’. (Student C, male, Interview 2)

‘That one [the activity with the flower models] was fun actually.’ [Interviewer asks what was fun] ‘That you got to move around.’ (Student G, female, Interview 4)

**Discussion and outlook**

The teaching approach provides a glimpse of the broad range of possibilities provided by 3D printing technology in biology education. This technology can be used in both formal settings such as schools and university, as well as informal settings such as botanical gardens and science centres, to teach about botanical topics such as flower diversity. Furthermore, the interviews clearly show that learners appreciated interacting with the models, as indicated by their high levels of motivation, positive learning experiences, and gains in content knowledge. As such, the evaluation underscores that the general benefits of 3D printing technology described in literature (Ford and Minshall 2019; Liziero and Ivete Basniak 2019) are also applicable to teaching about flowers and their diversity.

From a content perspective, the approach highlights the diversity of flower shapes and colours based on real examples (e.g. cherry flower with white petals and open shape; primrose with yellow
petals and tube in intermediate length; pink flower with pink petals and long tube), which could mitigate the limited knowledge about plant species diversity (Bebington 2005; Pedrera et al. 2021). In addition, the interviews showed that this knowledge was also applied to ecological aspects, namely to how the diversity of pollinators relates to the relationship between pollinators and flowers. An increased awareness of the diversity of organisms could potentially enhance people’s understanding of ecology (Pilgrim et al. 2008) and even peoples’ conservation engagement (Breitschopf and Bråthen 2023), which are both negatively impacted by a lack of biodiversity knowledge. This could be an interesting field for further educational research to explore how knowledge about flower diversity relates to understanding plant diversity and ecological and conservation-related aspects.

The approach can be linked with learning about common wild plants, including plants that are considered as ‘weeds’ in lawns. Bringing the flowers of ‘weeds’ to the forefront gives learners the chance to discover and experience their diversity, which could be a potential pathway to convince people not to ‘weed’ native wild flowers that support pollinators from their gardens (Majewska and Altizer 2020). This idea of bringing inconspicuous flowers into the spotlight was successfully tested in a prior educational project focusing on the plants on the way to school, where participants created a nature gallery by placing a picture frame around a plant or another organism that they especially valued on the way to school (Lindemann-Matthies 2005). That project led to positive effects on students’ botanical learning and interest, and a higher appreciation of wild plants. Hence, the 3D-models could be combined with approaches that focus on wildlife gardening (van Heezik, Dickinson, and Freeman 2012), such as planting wildflowers and creating habitats for insects, to create awareness of the morphological and functional diversity of wild plants and their importance for insect pollinators.

The interviews revealed that the flower models facilitated the expansion of students’ knowledge about plant and pollinator diversity. This knowledge is crucial from a pollinator conservation perspective as a high diversity of flowers is essential to support a diversity of pollinators (Goulson et al. 2015) and maintain ecosystem services (Isbell et al. 2011). Furthermore, the presented teaching approach focuses on the functionality of flowers, the process of pollination and the co-adaptation of plants and pollinators. This is a valuable addition to traditional textbook-based education, as textbooks often lack content on these interesting functional aspects and adaptations of plants (Schussler et al. 2010). However, it is important to be aware of common misconceptions in the field, such as mixing up pollination and seed dispersal, and explicitly address them in teaching.

The presented approach demonstrates how 3D printing can aid teachers in preparing engaging educational materials. Although similar models can be crafted by hand (Dreesmann and Kissi 2020; Gubo 2019; Lampert, Rose, and Kiehn 2015), it requires time, tools, and specific skills. The effort needed to create durable handcrafted models increases substantially. In contrast, 3D-printed models can significantly reduce this effort. While the initial setup and familiarisation with the 3D printer may take some time, the material costs for each model are very low once the printer is available. In contrast to typical handcrafted models, it is possible to assemble and disassemble the parts of the presented flower model without any glue or tape, which allows thorough investigations of the flower structures.

Another possibility to use the 3D-technology for botany education are student-led modelling approaches, in which students design their own flower models based on original flower templates (Bonorden and Papenbrock 2022; Bonorden et al. 2022). Modelling approaches take more time, but they provide the possibility to teach about plants in other subjects and can motivate students that are more interested in technology. Potential future interventions could explore the possibility of working with the modelling of flowers or other plant structures in interdisciplinary approaches, e.g. by combining arts, biology/science, mathematics, technical subjects, and computer sciences. This could be an innovative way to challenge the perception of botanical topics as being boring (Elster 2007). Modelling approaches allow learners to develop modelling skills that can be applied in other subjects and fields beyond biology. Developing modelling competence is also highly relevant for biology learning (Upmeier Zu Belzen, Van Driel, and Krüger 2019).

There is a high educational potential in combining existing approaches for 3D-printing of flowers. One way to do this is by using already designed flower models with a more realistic
flower morphology (see e.g. Bonorden and Papanbrock (2022)) and allow students to interact with those models in a similar way as presented in the role-play. Such an approach would enable students to explore the morphology and functionality of common wildflowers. For this, it is necessary to make good examples of 3D-modelled flowers publicly available for educators on public 3D-printing databases. Another way of combining modelling approaches with the role-play is that students first design and print flower models and then engage in role-playing with their own built models. In any approach, the learners should be encouraged to think critically about the relation between flower model and original object.

The main aim of this contribution is to encourage and inspire both biology educators and researchers in the field to explore the potential of 3D printing for educating about botanical topics. The models create opportunities for students to experience and reflect the diversity of flower structures, which can support students in understanding how plants vary. Moreover, 3D-printed flower models can create hands-on experiences and raise awareness of how flower diversity links to pollinator diversity from an ecological perspective. These experiences open up room for discussions that go beyond morphological aspects, but address issues such as biodiversity decline and how a variety of plants can support pollinator conservation.

Therefore, 3D printing a diversity of flowers or other plant parts can support educators in creating plant awareness and addressing sustainability issues. Future educational research can play a vital role in developing and testing further learning approaches that use innovative technologies to mainstream the relevance of plants for a diverse and sustainable future.

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Peter Lampert: Conceptualization, Methodology, Investigation, Writing – Original Draft, Writing – Review & Editing, Visualization, Project administration, Funding acquisition.
Peter Pany: Validation, Writing – Review & Editing
Niklas Gericke: Conceptualization, Methodology, Writing – Review & Editing, Project administration, Supervision, Funding acquisition.
Ethics statement

The project received ethical approval of the researchers’ institution (Karlstad University Ethics Committee, approval number HNT 2022/187).

All participants and their legal guardians were informed about the purpose of the study and gave their written consent in taking part in the research.

References


Eldebekey, S. M. 2021. “High School Students’ Experience of a 3D Printing Station at a Bilingual School Makerspace in Kuwait.” *History.* https://doi.org/10.21428/8c225f6e.5c7a27a0.


Linné, C. V. 1751. “Philosophia botanica.”


