TIPS, TRICKS & TECHNIQUES

Mobile Botany: Smart Phone Photography in Laboratory Classes Enhances Student Engagement

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Abstract

In our first-year university botany classes at Charles Sturt University, we noticed that in laboratory class, students were taking photographs of their specimens with the dissecting and compound microscopes using their mobile phones. Student-generated images as "learning objects" were used to enhance the engagement of all students, including Distance Education students who used images provided by the on-campus students. The Distance Education students did all the laboratory work at an intensive residential school, and they were encouraged to take images; these were shared with on-campus students, making them aware of the laboratory practical work they were yet to do. In other cases, images from students were incorporated into lectures and tutorials, preparing students for the lab exam. Botany students have shared their photomicrographs with their friends and family via social media. We saw interesting examples of students excitedly describing their images to non-science friends, teaching them what they were learning! In the second year, students were also encouraged to use their phones to capture their own images of plant specimens to help them master plant identification. Although we do not have any quantitative evidence of these activities enhancing student learning, it was evident that those students who took and shared their own images were more engaged in the learning process.

Key Words: *Collaborative learning; mobile phones; sharing images; teaching images.*

○ Introduction

The study of plants has never had the same attraction for students as the study of animals. This phenomenon has been termed "plant blindness" (Wandersee & Schussler, 1999; Balas & Momsen, 2014) and is a concern, given the central role that plants play in our lives (Uno, 2009). We have been investigating ways to increase awareness of plants by our first-year students (mainly enrolled in agricultural degrees) and have used strategies such as an interactive Supermarket Botany website and practical activities in which students learn about the plant parts they eat in a fun and engaging way (Burrows & Harper, 2009, 2012). Although most of our students have grown up on farms, they have assimilated only a little plant knowledge (Burrows, 2012).

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We have refined our laboratory practical exercises over the years for our first-year, on-campus, and Distance Education university students to maximize the amount of hands-on exercises, recalling the Confucian quote translated as "I hear, and I forget. I see, and I remember. I do, and I understand." So, in our laboratory classes, students get to "do" a lot, such as test hypotheses on photosynthesis through experimentation, germinate seeds under different dormancy-breaking conditions, plot graphs of their experiments (e.g., elongation of mutant pea plants after gibberellin hormone application; germination rates of *Acacia* seeds after different dormancy-breaking treatments), dissect apical meristems and flowers, and identify fruit types. These activities, coupled with interactive online preparative exercises (Google: "CSU Virtual Herbarium") have received favorable comments from students, both informally and in online evaluations.

In an unexpected development, students have recently started, of their own volition, to use their mobile smart phones to capture images of their microscope specimens and experimental results. What surprised us was that students persevered in taking images down the microscope, even though initially it took some trial-and-error to get a good photograph. The difficulty was due to the constraints of matching the phone's camera lens to the correct focal distance from the microscope eyepiece lens and then holding the camera steady enough to take an image. We appreciated the added value of students capturing their own images, as we believe this helped students create their own knowledge in a more meaningful way. We encouraged students to share their images with us and their peers. As we will discuss, this has had a very positive influence on student engagement and adds to the increasing number

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of uses being made of smart phones to enhance learning and communication opportunities across a wide range of activities.

○ Results

Optimizing Photography of Microscopic Specimens

After some trial-and-error and discussion with students, using different mobile phones, we worked out a way to consistently obtain high-quality images. We recommend the following procedure:

1. Set up microscope for bright field (Köhler) illumination to optimize image clarity.
2. Align the mobile phone's camera lens with the microscope eyepiece.
3. The point of convergence of light from the lens is approximately 1.0–1.5 cm from the eyepiece. A finger placed between the lens and the camera can help achieve this distance and also stabilizes the phone.
4. Move the camera back from the eyepiece lens slowly until the image fills the field of view. Adjusting the level of zoom can also be helpful at this stage.
5. Autofocus by touching the camera screen.
6. Hold the camera steady and take photo.
7. Check sharpness of image and retake if image is not sharp enough.

To set up a mobile phone to more consistently take images, we used a retort stand to hold the phone in position at the appropriate focal distance from the eyepiece lens (Figure 1A). There are also microscope phone adaptors available for sale on the web that can be used (Google: "mobile phone microscope adaptor"), and some instructions on YouTube for making your own! Although the retort stand made it easier to take images, it was an obstruction when it came to actually looking through the microscope. We appreciated the ability of students to hand-hold their mobile phones to quickly take an image down the microscope and then carry on using the microscope.

Apical Meristems

To help students appreciate the small size yet significance of apical meristems, in our botany laboratory practical classes we have them dissect a shoot apex of lavender (*Lavandula*) under the dissecting (stereo) microscope. This is a difficult exercise, but the outcome always amazes students when they realize that this delicate domed structure, <0.1 mm in diameter, produces the cells that give rise to the stem and leaves of the plant. One student was so proud of his dissection, which was much better than the two-dimensional representations in textbooks, that he attempted to take an image of the shoot apex through the dissecting microscope using his phone. We were so impressed with the quality of the image that we asked the student to e-mail it to us, which he did from his phone (Figure 1B). We also asked permission to use the image to teach other students. The image was subsequently labeled and placed on the home page of the Botany online teaching site, so that all other students could benefit from it. In addition, an unlabeled image was placed on the resources page so that students could test their recall of the key parts of the shoot apex.

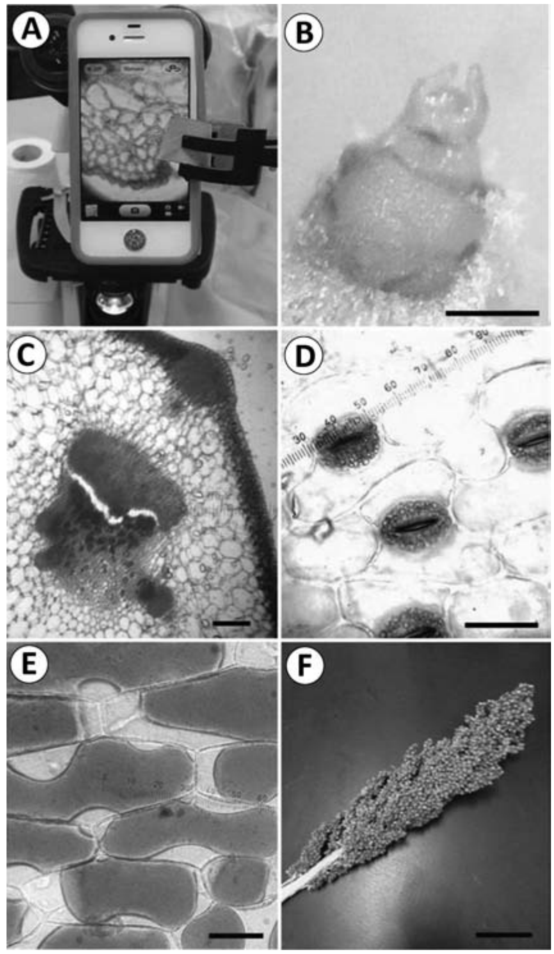

Figure 1. (**A**) A retort stand could be used to hold the phone at the correct distance from the eyepiece lens to take images – in this case, a prepared slide of a leaf section. However, this setup precludes the use of the microscope for student viewing. (**B**) Image of a lavender (*Lavandula*) shoot apex taken through a dissecting microscope. Note the small size of the apical dome from which the new cells for the shoot and leaves arise. Note also the youngest pair of leaf primordia (scale bar = 200 μm). (**C**) Free-hand sections of fresh specimens, such as celery (*Apium graveolens*) petiole, represent a useful way for students to see the connection between the plant and its underlying support tissues. Students can then identify different tissue types, such as collenchyma (top right-hand corner), parenchyma (most of tissue), and leaf vein (middle of section) (scale bar = 250 μm). (**D**) Epidermal peel of *Agapanthus* leaf showing stomata, guard cells, and other epidermal cells. The eyepiece graticule was captured as the photograph was taken down the eyepiece lens. The graticule can be used to measure guard-cell size and density (scale bar = 50 μm). (**E**) The shrinkage of the anthocyanin-containing vacuole of a red onion (*Allium cepa*) epidermal cell during plasmolysis is captured using a mobile phone camera (scale bar = 50 μm). (**F**) Mobile phone cameras can also be used to record images of plants for mastering of plant identification. Here a photograph of a sorghum (*Sorghum bicolor*) panicle was taken in a second-year agronomy class and the species name photographed separately to create flash cards. These images are shared by students via e-mail and on Facebook (scale bar = 5 cm).

Fresh Sections

Free-hand sections of fresh plant material, such as a celery (*Apium graveolens*) petiole (leaf stalk), were made by students and used to show the different cell types (Figure 1C). Again the student images were shared with other students and us, via e-mail, and placed on the online learning site for revision purposes (labeled and unlabeled).

Epidermal Peels

Epidermal peels of *Agapanthus* leaves are used to show stomatal arrangement, density, and size (Figure 1D). In this case, the student who took the image has captured the eyepiece graticule as well. Dedicated microscope cameras do not take an image down the eyepiece, so this important scale for calculating stomatal cell size and density is missed. We therefore used the student's image for teaching purposes by showing how many micrometers each eyepiece graticule represented at each magnification and correlated this with a calibration using a stage micrometer.

Plasmolysis

In yet another exercise, students use red onion (*Allium cepa*) epidermal peels to demonstrate the effects of salt solutions on plant cells, and this links into osmotic processes within cells and tissues. The red anthocyanin dye that gives red onions their color is held within the large liquid-filled vacuole of these cells (Wiltshire & Collings, 2009). A concentrated (5%) external salt solution causes water to leave the cells by osmosis, and so the cytoplasm pulls away from the cell wall and the vacuole shrinks. This phenomenon, called plasmolysis, was captured by students using their phones and shared with others (Figure 1E).

Recording Laboratory Results & Plant ID

As well as being very useful for sharing microscope images, mobile phones have been used by students to capture and share images of their experiments. In a second-year subject, Crop Agronomy, students use their mobile phones to create flash cards of agronomic plants that they must recognize as part of their mastery of the subject (Figure 1F). In addition to sharing their images with each other and us, students have shared their images via social media and e-mail to friends and family. This has resulted in students explaining the significance of the images to people not trained in science. The increased interest that the students had because they were creating their own images for learning and teaching others was exciting.

○ Discussion

Plants are often considered "poor relations" of animals when it comes to generating enthusiasm from students (Hershey, 1993; Uno, 1994; Wandersee & Schussler, 1999; Lindemann-Matthies, 2005). We have endeavored to increase student awareness of the importance of plants through a number of initiatives, which include interactive online resources and hands-on laboratory practical activities featuring various aspects of plant growth and development. We are encouraged further by the spontaneous use, by students, of mobile phones to archive and share teaching images. We have capitalized on this by using student images online to enhance learning, especially for Distance Education students.

At its heart, what we have described here is an example of the growing practice of students being "coproducers" of learning resources through the use of emerging technologies (Rikfin et al., 2011), a practice that improves engagement in and ownership of the learning process. The pervasiveness of mobile technologies and social media is responsible for the traction, momentum, and appeal of this approach.

Mobile phones and devices are beginning to be used for education in diverse ways. For example, in developing countries, isolated laboratories can share pathology images, taken with a mobile phone down the microscope and sent by Multimedia Messaging Service, and so improve diagnosis (Bellina & Missoni, 2009). More recently, Sumriddetchkajorn et al. (2012) have demonstrated the attachment of lenses to mobile phones to turn them into field microscopes. Digital cameras have been used in the classroom to chart the changes in plants during the progression of seasons (phenology; Magney et al., 2013), and GPS technology has been used to locate botanical specimens in the environment and improve students' key scientific skills (March, 2012). There are a number of recent reports of using student-generated online "campus floras" to provide an innovative way for students to experience botany first hand (e.g., Pettit et al., 2014; Struwe et al., 2014). "Campus Flora," from The University of Sydney, is a mobile iPhone app that maps the plants on campus along with information relevant to the botany curriculum (Pettit et al., 2014). These examples demonstrate undergraduate students producing botanical learning and teaching content and, in so doing, increasing their authentic learning opportunities in plant education and beyond. An example of "Beyond" is how student entomologists are using the Campus Flora app to find the right species of *Eucalyptus* to feed their stick insects and to locate termite colonies.

Mobile phones and other handheld devices hold promise for improving the educational outcomes of millions of people in developing countries through access to online education (Valk et al., 2010). Mobile technologies appear to be expanding the educational possibilities in the sciences by engaging students in documenting and sharing their scientific observations; in plant science, this notion is being extended to student-generated video learning resources (e.g., Martin et al., 2014).

With our students' help, we are investigating the possibility of building a repository of high-quality, accessible botanical images to share with other students, and primary and high school teachers, directly and placing these on our school's website as a freely available, student-generated resource. When students were asked how taking their own images helped them, they generally responded that it helped them make better connections with what they were learning. We will leave the last comments to some of our first-year agricultural students whose words capture this:

- "Taking photos assisted me once I left the lab. It was much more useful than just looking at a photo on a lecture slide, as I had personally prepared that sample and set it up under the microscope. We are so bombarded with information sometimes it's hard to remember everything, but this allowed me to really remember, understand and comprehend what I was learning."
- "I got to review what I saw and it helped reinforce things."
- "Taking photos with my mobile and then looking at them gave my eyes a bit of a rest from focusing down the microscope."

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