

Taking a Second Look: Investigating Biology with Visual Datasets

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Have you considered the use of biological images as populations to be sampled? Visual datasets allow students to practice necessary visual skills and explore visual approaches to problem solving within specific areas of biology. Examples of visual datasets being used in undergraduate courses as well as new visual datasets are presented with an introduction to some of the visual learning strategies. Proactive design of visual learning experiences within the biology curriculum is urged.

KEY WORDS: visual learning, images, datasets, instructional design

The study of biology presents a unique set of visual learning, visual thinking, and visual communication requirements. Students majoring in the biological sciences not only should develop specific visual methodologies, e.g. the microscopic examination of tissues, field identification of organisms, or interpretation of graphic laboratory results, but also be able to utilize their knowledge of images for thinking and communicating within the extensive visual culture of practicing biologists. Knorr-Cetina & Amann (1990, p. 259) note that “the focus of many laboratory activities is not texts, but images and displays.” These are not passive media, but “objects on which work is performed in the laboratory; like other materials handled in the stream of laboratory activities, they are processed” (p. 262). Students should be able to examine these images critically for additional information about the process or source material used to generate them. They should be able to understand the limitations of their own perceptions as well as the tools used to obtain visual information. Most importantly, they must continue to build and rely on visual skills and knowledge throughout their educational and professional lives.

How can we design learning environments that support our students in these objectives? Experiences that integrate visual learning with specific content should be part of the courses we offer. Visual learning can be defined as “the acquisition and construction of knowledge as a result of interaction with visual phenomena” (Seels 1994, p.107). Visual learning is an important component of visual literacy, “the ability to understand and use images, including the ability to think, learn, and express oneself in terms of images” (Braden & Hortin 1982, p. 41). Despite the abundance of images we expect our biology students to be familiar with and use effortlessly, what it means to be visually literate in biology has been largely ignored. With the escalating use of images in our networked

society, this expectation increases. The conceptual frameworks of visual learning and visual literacy are essential in the study of all disciplines, not just the biological sciences.

By selecting biological images from specific areas of biology that allow students to practice necessary visual skills and explore visual approaches to problem solving, we can offer visual datasets for use in our courses. A visual dataset may consist of a single image or a group of related images. Each image can be explored through multiple means to provide additional qualitative and quantitative data. Often additional information about the images is provided such as magnification or scale, source material may be identified, or the process by which the image was produced is revealed such as scanning an object. Most images we interact with have the potential for further study, but for the purposes of this paper, visual datasets are images explicitly produced for the purposes of visual analysis.

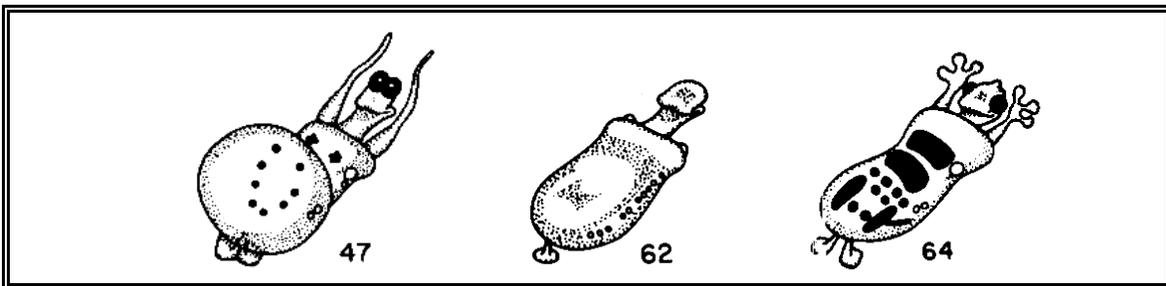


Figure 1. Examples of figures from the Caminacules.

One example of a visual dataset is the **Caminacules**, an imaginary group of organisms generated by J. H. Camin and described by Robert Sokal (1983, pp. 161-163) that can be used for problem solving activities in evolution, classification, and development. The popularity of this dataset is shown by its inclusion in a variety of curricular materials such as *Biology Laboratory*, an introductory lab manual (Eberhard 1987, p. 161) and *The BioQUEST Library* (Jungck & Vaughan 1996) on CD-ROM. Each caminacule has a distinct set of phenotypic characteristics which can be used to organize the images into groups. Students "visualize" an evolutionary history for the caminacules by constructing a phenogram. Relationships between individual caminacules are determined by the identification and weighting of characters by the students. Despite preferred phenogram results by some instructors, this problem solving experience clearly provides for a rich set of "solutions." It also opens the door for active persuasion based on visual interpretation and logic since these imaginary organisms can not have their behaviors observed, nor their molecular components analyzed. The inclusion of some fossil data (extinct forms) in the large dataset provides new information that obligates students to re-evaluate their visual data.

There are large visual datasets accessible by most instructors and students that exist at your institution. The microslide collections that can be found in every biology department

are incredible visual resources. Despite this, learning experiences with prepared slides are often reductionistic. “Undergraduate students often view light-microscopy laboratories as memorization based courses. Too frequently the only major objectives of such courses is the descriptive naming of microstructures” (Blystone & Blystone 1994, p. 125). It may not occur to students to investigate the microscopic material beyond the identification of structures or an overview of the arrangement of these structures. More data is there than meets the eye and it may be used to enhance their understanding of biology.

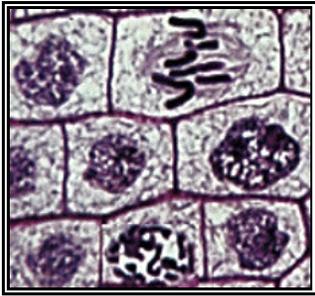


Figure 2. Longitudinal section of onion root tip as observed by light microscopy at 430X.

Let's consider the use of a slide with a longitudinal section of an onion root tip in introductory biology. This slide is an excellent source of cells showing various mitotic phases. The process of "visualizing mitosis" (Milne & Milne 1958, p. 99) by making a microscopic examination of this tissue has long been a standard laboratory practice. Students are usually asked to identify cells undergoing specific phases. Even students who are not in the laboratory setting may be asked to do this by examining micrographs in their textbook (Campbell, Mitchell, & Reece 1996, p.147). A significant extension of this task is to quantify the cell cycle (Eberhard 1987, p.103) by examining individual root tip slides in lab. Using root tip tissue to learn about mitosis is not new (see Robbins & Rickett 1929, pp. 186-187). However, asking students to gather data from these images by treating the cells as populations for statistical review is an important pedagogical breakthrough. By actively investigating the number of cells in interphase and various stages of mitosis, students have the opportunity to develop an understanding of the reproductive process integrated with their knowledge of structure of the plant. Terms used to describe cell structures visibly associated with specific phases are acquired by students through the repetitive process of counting phases. (There's nothing like a bit of extended visual practice to familiarize yourself with these distinctive features.) The differing results shown by individual counts allow students to address the issue of variability in living systems. Since there is not one correct "answer" to the phase frequency question, a robust set of questions concerning methods of counting and identifying as well as expectations may arise.

Blystone & Blystone (1994, p. 125) describe a wonderfully extended student approach to histological material from an inquiry-based learning perspective where students "view images as datasets." By using image workstations that support digital video microscopy, students can manipulate images that they capture directly from

examination of their own slides or provided as digital images by the instructor. Students have access to powerful digital processing software such as NIH Image and Adobe Photoshop which allow them to perform a variety of measurements and manipulations. Examples of this include measuring inner and outer diameters of proximal versus distal tubules in a slide of rat kidney cortex in order to consider functional differences in these structures, creating digital serial sections through the kidney slide and recombining them to reveal a 3-D nephron, and reconstructing a chick embryo by combining several of the serial sections that have been captured from a single slide. Their students learn biology by constructing “visual hypotheses, simulations, and models” (p.131).

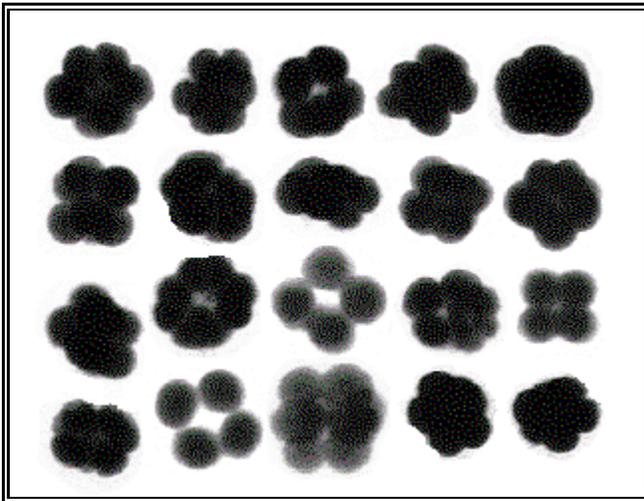


Figure 3. Starfish embryo dataset from Image Analysis.

Visual resources are increasingly available. Visual databases from many areas of biology are available on CD, laser disc, and the web. Visual datasets are also being published in both text and digital forms. Some of these datasets come with an explanation of the pedagogical implications of their use. The visual dataset of starfish embryos (Blystone & Cooper 1996, p. 64) enables students to explore their understanding of embryogenesis and development as well as increase their understanding of how images are manipulated and chosen for publication.



Figure 4. “Whole” plant image from Oh Phlox!

Oh Phlox! (Stanley 1996, p. 90) includes image files of individual leaves and “whole” views of mature garden phlox plants. It was developed to encourage visual practice prior to and following field study as well as support visual investigation in biology. Care was taken to reduce the aesthetic bias that is often present in published images of flowering plants by incorporating all the phlox plants in a randomly selected area as images in this dataset. These unlovely specimens also contain “missing information” where occasionally leaves are missing or overlap each other.

How can we use datasets in our courses? There are several worthwhile approaches we can take. Let's begin by considering the leaf images from Oh Phlox! as a population to be sampled. Can we use this population to challenge some of the misconceptions or under-investigated biology of leaves? "In most studies of crop canopies or of the foliage of single plants, all leaves are treated as if they had the same properties" (Harper 1989, p.105). By systematic examination of these phlox leaf images, students can easily see that leaves are highly individual. They are much more likely to appreciate that "leaves on a plant or in a crop form a population, an assemblage of things that can be counted, and they are manifestly not all the same. Their heterogeneity derives in part from the fact that they (like a population of rabbits in a field or of blue tits in a woodland) are not of the same age and change their properties as they age" (p. 105). Access to whole plant images as well as individual leaf images allow students to examine the leaves with respect to the development of the plant. The stem of the plant can be viewed as a transect through time. This "timesect" perspective provides visual information that is often overlooked by observers. Leaves can be considered in light of their individual and social context. Harper (1989, p. 105) points out the significance of looking at leaves "borne in different positions relative to each other" that "determine which leaves shade which. The positions they occupy within a canopy are also related to their age- in general, young leaves are found in the fringes of a canopy with older ones in the shade." Students can use Oh Phlox! to explore the biology of the mature plant through visual inspection and gain the practice they will need to carry out field investigations in the future.

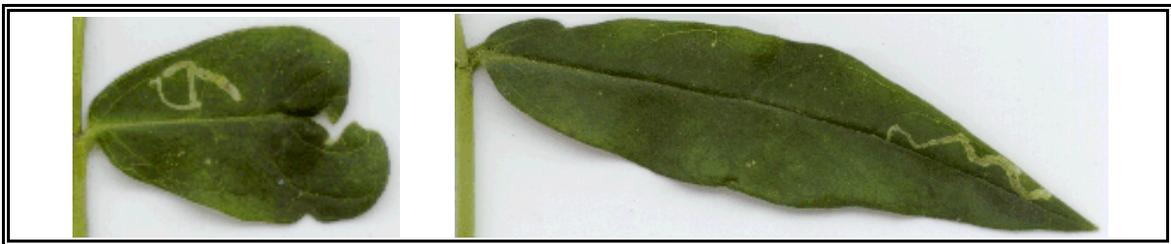


Figure 5. Selected leaf images with leaf miner damage from Oh Phlox!

Students could initiate their own investigations by sampling any of the myriad features of this population. They can develop hypotheses and use statistical data to support their ideas. Investigations centered on this dataset might include some standard measures of physical traits such as number of leaves per plant, percent of leaves showing leaf miner damage, average surface area of leaves, or leaf damage per individual leaf miner as an estimate of feeding required by developing larva. A fairly low tech estimate of leaf miner damage can be done by enlarging and printing out the image of the leaf, trimming the image, and determining the weights of the entire leaf and leaf miner "trail." (Selected areas could be enhanced and then quantified with a digital processing program like NIH Image as well.) Behavior could be studied by determining directionality of leaf miner trails or plant growth responses after endoparasite activity. Students might examine the timing of leaf miner foraging by studying the intervals between leaves with leaf miner damage.

Students could measure “green” or pixel density in new versus "old" leaves, analyze leaf shape as evidence of nutritional deficiency. An “eye-opening” experience for many students who tend to rely heavily on illustrations to identify plants in the field is to have them build a model of the “average” leaf from this population to compare with phlox leaves found in their field guide. Student directed activities could extend well beyond this list.

This increase in visual resources that support visual learning is not enough if we do not incorporate them in our courses. There are some questions we can ask ourselves that may help in making decisions about whether or not we should include visual learning objectives as part of our instructional design. Are the images we use in our lectures essential? Do our students question these images or merely memorize them? Gould (1987, p. 16) stated, “scientific illustrations are not frills or summaries; they are foci for modes of thought.” Do we believe this? Are the images we encounter in journals important? If so, where will these images come from in the next generation of biologists? Do we rely on any visual strategies and knowledge that are specific to our discipline? Do our students find visual approaches to investigation in the laboratory or field problematic? If so, let’s reconsider the role of visual learning in the design of our courses.

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