
Interactive learning in biology

with PhotoCD and associated software

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This paper describes the pioneering development of flexible-learning courseware in the teaching and learning of cell biology using a novel optical disk-based technology – PhotoCD – and its associated computer software. The use of this format in an educational context for the manipulation of, and interaction with, photographic images in electronic form is presented for the first time. Examples of courseware which use PhotoCD, image-enhancement and image-management software in biology education are given, and an evaluation by undergraduates in biology education (student teachers) of these teaching and learning strategies is presented.

PhotoCD: what is it?

PhotoCD is a novel electronic format which uses digital technology to scan colour or monochrome photographs, store them on compact discs, and then display them as high-quality images on a TV or on a monitor screen. A technical description of this technology can be found in Beisner (1993), Bowers (1994) and Chen (1993). Supporting software is available to access and manipulate the images for use in interactive learning.

PhotoCD equipment and materials

Hardware

A PhotoCD player (Kodak PCD 5865) displays images directly from PhotoCD to TV or monitor screen. The player can:

- automatically display the images in sequence;
- allow two, six or eight seconds' duration of display during an automatic slide-show sequence;
- eliminate undesired images from the sequence (skip);
- allow random access to images;
- pan left and right across the screen image;

- rotate the image in 90° increments;
- display a 2× enlargement of a part of any image; this is achieved by positioning a rectangular cursor on the required part of the image using four direction buttons on the remote control unit;
- remember the format of edited images;
- restore edited images to their original format;
- display a reduced version of the complete image;
- play audio CDs at high-quality sound.

A portable PhotoCD player (Kodak PCD 885) enables the system to be used in any teaching room, off-site for outside lectures, presentations etc., or to be taken home where it can be plugged in to a domestic TV set.

A colour monitor (Philips 8833 MkII 34cm CGA) gives higher-quality resolution than is possible with a standard TV for use by students in the classroom for individual or small-group learning.

A microcomputer is used for DTP and image manipulation.

Software

Appropriate software, in addition to desktop publishing packages, is available to be used in conjunction with a computer and a suitable CD-ROM drive.

PhotoCD Access (Kodak) allows images to be called onto the computer screen. It can be used to rotate, flip, crop, and cut-and-paste images into other applications. It allows multiple versions of the same image to be opened.

Shoebox (Kodak) is an image-management program which creates thumbnail representations of images. These are then used to create a flexible index using descriptive information for storage and retrieval. This graphical database application allows the user to search, count, mark, and display the digitized images stored on PhotoCD. It can also be used to zoom, crop, copy and paste images into other applications, view a slideshow of images, and store information from other formats. It is possible to print out any edited contact sheet or individual image.

PhotoEdge (Kodak) is an image-enhancement program which allows detail to be added or deleted from the image: exposure adjustment, sharpening and softening, colour correction, cropping, zooming and panning, and addition of arrows and script. It can be used to access PhotoCD images, display contact sheets, adjust brightness and contrast, and resize and rescale images.

Images

The PhotoCD we used contained micrographs of ultrathin (>1 μm) sections of animal cells and tissues taken at very high magnification (×1200 – <×20k) through an electron microscope (such instruments are used mainly for research, and these images were taken

from the authors' own work). Transfer to the PhotoCD format from 35mm monochrome slides was by commercial process via a high-street photographic retailer.

Why is PhotoCD important for biology education?

Obviously, PhotoCD is not uniquely suitable for biology education, but visual images are fundamentally important in the study of biology. Students' understanding of biological processes requires observation of suboptical structures and their related functions, and first-hand observation and experience traditionally is gained by using a microscope. An increase in our understanding of biological function at the molecular level has occurred with the development and refinement of microscope technology. With few exceptions, however, such instruments are funded by large research grants, and are rarely available for the use of undergraduates. In circumstances where students are not specifically being trained in microscopy, where, as is the case in many general or introductory courses, acquisition of overview or basic level of understanding is required by the course, PhotoCD is an affordable and flexible alternative.

Practical applications of PhotoCD

There are many practical applications of PhotoCD, some of which we list below:

- Illustration of teaching points during lectures, tutorials or seminars. Portable PhotoCD players, handset operated, can be used to display, highlight, enlarge or rotate selected images to illustrate teaching points.
- Class interaction – students use the PhotoCD player in response to questioning, and in discussion.
- Practical activities – students work at practical problems directly on the images. Programming sequences of images, to demonstrate processes, measuring and comparing structures, and other aspects of biometry relating structure to function are examples of the use of PhotoCD in the study of microscopic preparations.
- Presentations – students work together or individually to produce presentations of their work. Original photographs or photomicrographs, or sequences of these, can be incorporated into text images to communicate students' understanding.
- Information retrieval – image management software is used to set up a visual database for students to question, or to add to with further information about the images.
- Supported self-study – individually, or in groups, students work at courseware which reinforces the subject matter of courses.

PhotoCD and associated software as a learning medium on trial

It has been demonstrated that students' understanding of biological processes is achieved more quickly when they use interactive learning technologies in conjunction with more traditional teaching methods (Huang & Aloï, 1991; Baggott & Wright, 1994). The strength of PhotoCD as a tool in teaching and learning lies in its application for freeing

the user from technical constraints, while allowing grasp of fundamental concepts. High-quality images can readily and repeatedly be studied at a relatively low cost.

The 26 students involved in our PhotoCD pilot study were biology education undergraduates at the University of Exeter, in the third year of a four-year course. These students are able to provide high-quality feedback on new learning formats as a result of their professional education combined with the variety of backgrounds from which they come to the course: there is a wider age range than is usual in undergraduate courses, and many come to teaching from other professions and occupations. In view of the fact that they are obliged to acquire a breadth and depth of scientific knowledge as well as professional expertise in practice, methods of gaining an accurate overview while encouraging a spirit of enquiry are especially relevant for their education.

Examples of courseware

The PhotoCD images were displayed on a monitor or computer-monitor screen, and the students worked at specific tasks relating to them. Various approaches were used in framing the tasks, but all required the students to make very close observations and to exercise their subject knowledge in discussion. The following are representative tasks using the PhotoCD images and software:

Examples of tasks involving use of a PhotoCD player

What is this structure? (Image No. 4)

With reference to your lecture notes and course handbook, annotate the image with information not only about the visible structures, but also the physiological processes leading to and resulting from, its development.

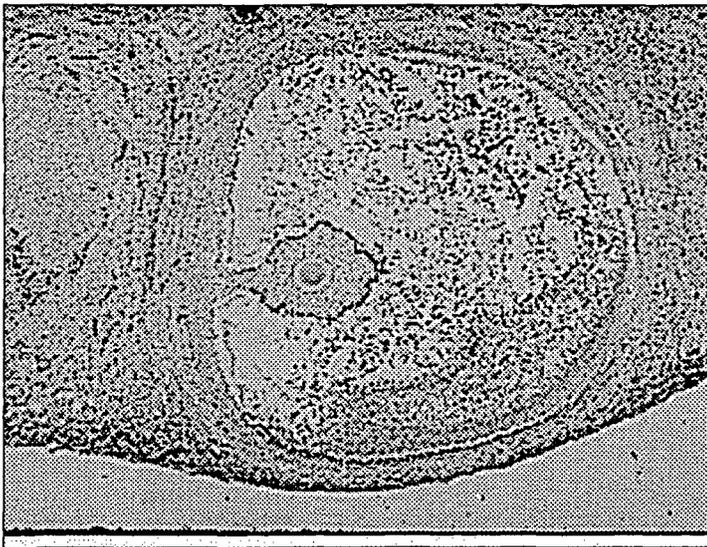


Image No. 4

Browse through images 20, 23, 43, 44, 45, 50, 56, to find a good example of a Golgi

apparatus. Use the zoom facility to magnify the organelle, and then make a labelled diagram of it, giving some indication of scale, and stating from which image it came.

Examples of tasks involving the use of image-enhancement software (PhotoShop)

Identify an image which shows a micrograph of oviductal epithelial tissue. Scan and print out an image with clear contrast and good definition. Label the features of particular functional significance for this tissue.

Scan and print out good copies of images 34 (oviduct) and 45 (epididymis). Compare and label the common features of these tissues. Annotate the copies to indicate the differences in function between the two tissues.

Examples of tasks involving the use of image-management software (ShoeBox)

Set up and print out a contact sheet containing images showing examples of a variety of tissues to be found in the mammalian female reproductive tract. Label each image, and provide suitable explanatory captions.

Search the catalogue for an image showing a clear example of oviductal epithelium. Print out the image, and annotate it to explain the function of the cell types contained in this tissue.

Student evaluation

There is a substantial academic component to the science education course at the University of Exeter, part of which is a sixty-hour course on developmental biology. The PhotoCD materials were used during this course to reinforce the students' understanding of the microanatomy of the mammalian reproductive tract. Clearly, there is insufficient time for such students to work directly from an electron microscope, and the study of electron micrographs gives limited information.

Students were given a demonstration of use of the PhotoCD equipment, and were left with written instructions for both hardware and software. They then worked through the courseware in their own time in groups of two to four. None had had any prior experience of working with an electron microscope: their study of biological specimens at the ultrastructural level had been via text-book micrographs and diagrams. They were asked to give their reactions to the PhotoCD materials in terms of perceived advantages and disadvantages, and how their motivation for learning had been affected.

All responded positively about the user-friendliness of the hardware, and the documentation for use. They were impressed with the quality of resolution, and the ease with they could move from image to image, pan, zoom and magnify. Some reported that work with a light microscope was usually a solitary activity, and they appreciated the collaboration and discussion which occurred when they worked together around a screen. The most valuable outcome for many students, however, emerged from the tasks with the image-enhancement software. There was a considerable sense of empowerment in taking home an accurate record of a microscopic image which they had studied together, and which could be further labelled, annotated and filed for future reference. This was

particularly apparent when hard copies resulted from tasks which involved questioning the database.

The majority of students (88%) felt that their interest in and enthusiasm for the subject had been enhanced by using the PhotoCD materials. Some (7%) said that their motivation had been unaffected, and 5% felt that as it was not 'the real thing', it was a pointless exercise.

Discussion

One skill which is traditionally practised in biology is drawing. Observation occupies a large proportion of the time spent in studying organisms, their structure, function and inter-relationships, and a key component of any scientific investigation is accurate recording. Although drawing has almost entirely been superseded in biological research by photography, it is still highly valued by many biology educators as a means of developing the skill of observation. However, it is a time-consuming skill to acquire, and relies to some extent on a combination of prior experience and natural talent. The traditional technique for drawing specimens from a microscope requires the observer to keep the paper on the side of the drawing hand, use the opposite eye for the microscope eyepiece, and keep both eyes open while looking from the specimen to the drawing (Jones *et al.*, 1994). This can be extremely tiring, and unless they can produce reasonably accurate drawings fairly quickly, it is probably an inappropriate use of time for undergraduate students. PhotoCD is a means of liberating them from this difficulty.

A previous intervention study, in which the PhotoCD materials were used by half the students on a first-year cell biology course following a pre-test, demonstrated that the post-test scores of those students who used the PhotoCD materials showed a highly significant improvement over the scores of those who had not used the materials (Baggott & Wright, 1994b). The sample size in both case-studies was small, and other factors such as the background knowledge of the students, or the fact of having done extra study because of their involvement in the trial, may have affected the outcome of their work. Nevertheless, in both intervention studies, the PhotoCD materials do appear to have positively affected either the learning of the students, or their motivation for learning. However, further detailed work is needed to make any assertive statements about the value of the materials for learning, and to elucidate the reasons for the improvement.

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