Digital Documentation: Merging the Traditional Laboratory Experience with Digital Imaging Technology

Bruce W. Robart, Kimberly A. Ziance, and Melonie J. Dropik

Department of Biology
University of Pittsburgh at Johnstown
Johnstown, PA 15904
robart@pitt.edu
kziance@pitt.edu

Education Division
University of Pittsburgh at Johnstown
Johnstown, PA 15904
dropik@pitt.edu

Abstract: In this investigation, students will become proficient in the use of integrated digital technology as they capture images of exemplary specimens with digital microscopes. Students can later use these images individually to compose and illustrate original lab manuals (digital notebooks) or in collaborative groups to design multimedia presentations. Students actively engage in their learning and participate in high levels of cognitive functioning as they construct knowledge about the phyla they are studying. The creative aspects of these exercises provide for a high interest laboratory experience that taps into intrinsic motivation and leads to student success in demonstrating content mastery.

Keywords: integrated digital technology, digital notebook, digital microscopes

Contents:

Introduction

Traditional organismal biology (botany, mycology, phycology, entomology, etc…) labs typically present the student with questions that guide them through an observational exercise in which they are intended to discover important characteristics about a single specimen that can be generalized to a larger group of organisms. Students sketch what they see and produce drawings that may be faithful renderings of the images they observe, but these renderings often fail to provide a visual representation that illustrates the important characteristics that make the specimen an exemplar worthy of study. Students lack the expertise to differentiate between the important characteristics that can be generalized to an entire phylum and the incidental artifacts of the particular image being studied. An alternative and innovative approach to accomplishing these types of laboratory exercises is presented in this workshop. This approach serves to promote scientific inquiry and provides students with a means of capturing actual images for further study.

In this investigation, students will become proficient in the use of integrated digital technology as they capture images of exemplary specimens with digital microscopes. Students can later use these images individually to compose and illustrate original lab manuals (digital notebooks) or in collaborative groups to design multimedia presentations. Students actively engage in their learning and participate in high levels of cognitive functioning as they construct knowledge about the phyla they are studying. The creative aspects of these exercises provide for a high interest laboratory experience that taps into intrinsic motivation and leads to student success in demonstrating content mastery of the subject at hand.

This type of digital documentation exercise can be adapted for any college biology laboratory at any level. The sample exercises used in this workshop are intended for an introductory level biology laboratory course. These activities described in this manuscript were selected to demonstrate the use of integrated digital documentation in a college laboratory setting. There are many other applications of this type of technology that can be used in the laboratory classroom.

Currently, as part of a grant funded by the University of Pittsburgh, we are incorporating the use of digital microcopy into our General Biology I and II labs. We are having the students generate digital microscopic images, label these images, and then attach these images into a hard copy, regular lab notebook. Also, the students are creating images to be included in a "Welcome to Biology Lab" introductory CD to be used in later labs. In addition, during some of the labs, we use the digital equipment as demonstration scopes set-up by the students at the laboratory tables. This exercise alone helps to further develop the microscopy skills of the students as they share their images with other students. We have also used the digital equipment to assist visually impaired lab students by enlarging the microscopic images for viewing on the on the lap top computer screen.

Goals

Overall Lab Course Goals using Digital Documentation:

- Actively engage students in learning
- Enhance student note-taking abilities
- Evaluate the quality of digital microscopy images
- Develop laboratory notebooks to be used as authentic assessment tools
- Create group digital documentation projects
- Develop microscopy skills

General Content Specific Lab Goals:

- Identify important morphological characteristics
- Recognize scientific terminology
- Discern the similarities and differences among organisms
- Identify and classify closely related organisms
- Synthesize visual information and discern which characteristics of particular specimens can be generalized to a whole genus, class, phylum, etc…

Materials

Digital Imaging Materials:
Digital Microscope Set-up (explained in detail in Appendix B)
Computer (Laptop computer is preferable)
CD-R (one per student group)
Software (MS Word, MS Picture, PowerPoint, etc.)

Sample Lab Exercises Materials:
Rhizopus prepared slides
Morchella prepared slides
Pezia prepared slides
Coprinus prepared slides
Rhizopus cultures, +/- strains
Fresh basiodiocarps
Blank slides
Coverslips
Powdery Mildews (Students will collect)
Pencils with erasers
Sharp dissecting probe
Plastic collecting bag
Key to North American Genera of the Powdery Mildews

Notes to Instructors

Rationale

Digital microscopy combines the magnification ability of a light microscope with the image capture capability of a digital camera. The nearly instantaneous capture of images greatly improves the immediacy between abstract concept and reality allowing instructors to forge this connection in real time. With traditional microscopes, this connection is often lost because instructor and student cannot simultaneously view and discuss the object; hence important details are often missed or lost in translation. Having a large visual representation as a referent, the instructor is able to identify the important characteristics that make the specimen an exemplar worthy of study and can point out the artifacts that are unique to the image at hand. Student misconceptions can be avoided and appropriate knowledge construction can occur more efficiently when the instructor and student have access to the same visual depiction of a specimen. Students can capture images to enhance laboratory reports, develop digital notebooks, or document biological phenomena for research.

Digital documentation can stimulate student interest in the lab material because most students enjoy using technology in the laboratory and are quite proficient at using the tools involved in this technology. Also, digital documentation can help students organize their lab information, and student generated pictures are meaningful to the students. Students will be less likely to "see and flee" because they will need to put forth effort to develop their lab notebooks. By tapping into intrinsic motivation, this approach provides an effective means to promote learning and active participation of students.

Recommended Experience: Students should have basic computer and microscopy skills to properly use digital documentation. To complete the sample lab activities, the students should have completed a General Biology course.

Preparation time needed by the instructor: Allow 30 minutes before lab to boot the computers and attach the microscopes. The time required to prepare slides and specimens depends upon what the lab exercise is going to cover.

Safety Concerns: Some students may be allergic to specimens. Those who have allergies should be cautioned.

A variety of digital set-ups are available in all prices ranges. Refer to Appendix B for equipment and vendor information.

Student Outline

General Project: Students are required to use digital microscopy/digital photography to document their lab assignments in their digital laboratory notebook. The notebooks are group assignments that will be completed during the entire term of lab. The notebook assignment could be completed as an individual project according to the instructor's preference. The completed project is submitted to the instructor on a compact disc (CD-R) at the end of the term.

The digital notebooks are graded using the following guidelines (checklist items):

1. Is the assignment complete? (All of the lab exercises have been completed, and each of the questions from the activities has been correctly answered.)
2. Are the digital images correctly labeled with the appropriate information?
3. Is the project well-developed? (flow of slides is appropriate)
4. Are the slides easy to understand? (slides have titles)
5. Is the project visually appealing? (pictures are clear, slides have sufficient color)
6. Does the project demonstrate creativity and innovation?

During the first lab session of the term, students are given the opportunity to view digital notebooks created by former students. They are asked to complete the following evaluation sheet to give them some ideas to help them get started with their digital notebook projects.

Student Evaluation of Digital Notebooks
Please circle a number in response to each question. The number 5 represents the highest score, and the number 1 represents the lowest score.

1. Is the project visually appealing? (pictures are clear, slides have sufficient color, etc.)	1 2 3 4 5
2. Are the slides easy to understand? (slides have titles, diagrams are labeled, etc.)	1 2 3 4 5
3. Is the project well-developed? (flow of slides is appropriate)	1 2 3 4 5
4. Do the slides contain detailed information? (explanations are included with the diagrams)	1 2 3 4 5
5. Is the assignment complete? (slides covered all of the required material)	1 2 3 4 5

General Comments:

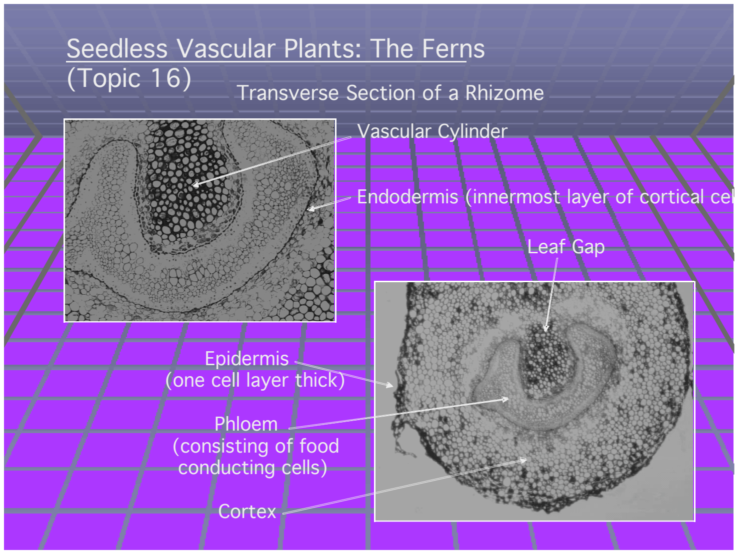
Please answer the following questions about the digital notebook project that you observed.

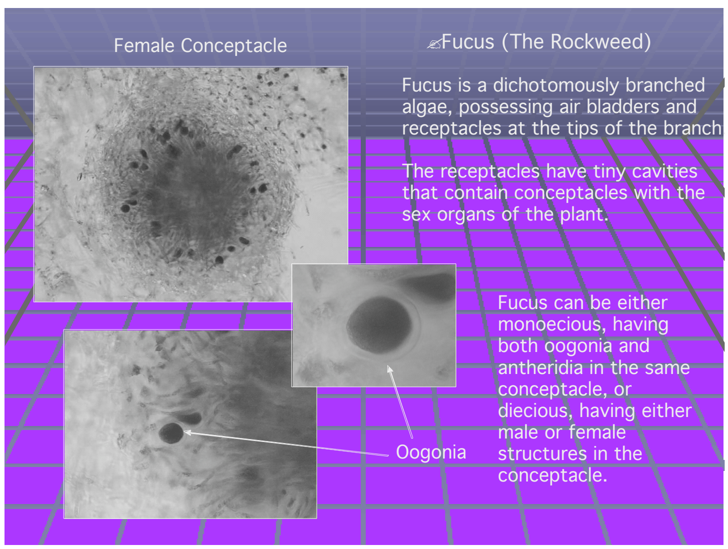
Does it appear that this group/individual put a considerable amount of effort into this project?

What aspects of this project really impressed you?

What did you dislike about this project?

Sample Slides from Student Digital Notebooks (Plant Biology Lab)





Sample Lab Activities Using Digital Documentation

Background Information: Zygomycota, Ascomycota, and Basidiomycota

Superficially, the members of the Kingdom Fungi have some features in common with true plants and some algae. Many kinds are "rooted" in the ground, they produce spores, and they have a thalloid type of body plan. But that is where the similarity ends. Fungi do not have chlorophyll therefore they are not autotrophic. Fungi are heterotrophs deriving their nutrition by either saprophytic or parasitic means.

The body of the fungus consists of fine filaments called hyphae, which become compacted collectively into a mass called the **mycelium.** The hypha may be divided by cross-walls (septa) or may have no cross-walls (**non-septate** or **coenocytic)**. Cells may be uninucleate, binucleate, or multinucleate. The cell walls of fungi are composed of **chitin** not cellulose.

Fungi reproduce by asexual and/or sexual means. Asexual methods include fragmentation, fission of somatic cells, budding, and production of spores. Asexual spores are either produced inside spherical structures called **sporangia** or are produced at the tips or sides of hyphae, in which case they are called **conidia.** Sexual reproduction in most fungi involves three phases: **plasmogamy, karyogamy**, and **meiosis**. Plasmogamy unites the protoplasts of two haploid cells so that two nuclei are together in a single cell. The paired nuclei of the resulting cell are called a **dikaryon**. Karyogamy is the fusion of the dikaryon into a single diploid (2n) nucleus. Meiosis restores the haploid number to the four cells that result from the process. In the following activities, you will explore details of the sexual reproductive process and general morphology of each phylum.

Activity 1: Phylum Zygomycota: The Conjugation Fungi

1. Examine the *Rhizopus* slide for individual hyphal threads. Do the hyphae have septa? Capture digital images to illustrate your answer to this question. Some hyphae produce **sporangiophores** each bearing a **sporangium**. These are sac-like structures full of spores produced from a single stalk, the sporangiophore. At the base of each sporangiophore are fine hyphae called **rhizoids**. Propose a function for the rhizoids. Find these structures, obtain digital images, and label them.
2. Examine the *Rhizopus* slide for zygospores. Mature zygospores are the large darkly stained (almost black) spherical objects covered with spikes. They develop between the side branches of two independent hyphae. Obtain images of zygospores in various stages of development and place them in order in your digital notebook. Include the following terms in your images: **zygophores, progametangia, fusion septum, suspensor cells, gametangial septa, zygosporangium**. If you are lucky, you may find a **germ sporangium**. Add this to your digital image collection and share this discovery with your classmates. Is the zygospore haploid or diploid? Is the germ sporangium haploid or diploid? Explain your answer!
3. Look carefully at the *Rhizopus* culture. The mycelia of two strains of the same species of *Rhizopus* were placed on opposite ends of the agar plate. What happened as the two individual fungi grew? What is produced where the mycelia of the two strains intersect? Now remove some of the fungus from the zone of intersection, make a wet mount, and obtain digital images of the structures you saw in part B. Make sure to label the structures.

Activity 2: Phylum Ascomycota: The Sac Fungi; *Morchella*.

1. Examine the slide of *Morchella*. This is a cross section of the ascocarp, that part of the fungal organism where spores are produced. Describe how the hyphae are organized into the mycelium. You should see three distinct organizational patterns. How are the terms **hymenium**, **hypothecium**, and **excipulum** applied to these patterns? What is an **apothecium**? Are the hyphae septate or non-septate? Obtain digital images to illustrate your answers and descriptions.
2. Now find the sac-like sporangia called **asci** (sing. **ascus**). They are easy to distinguish because they contain spores. What is the maximum number of spores in a single ascus? How does this number reflect the fact that the ascus is the site of meiosis? Why are there eight cells instead of four? How did this occur? Obtain digital images to illustrate your digital notebook.

Activity 3: Phylum Ascomycota: The Sac Fungi; *Peziza*.

- Examine the slide of *Peziza*. Using digital images and the terms from Activity 1, compare and contrast this fungus with *Morchella*. The hymenium of *Peziza* also has **paraphyses**. What are these structures? Make sure to label them in your images.

Activity 4: Phylum Basidiomycota: The Club Fungi; *Coprinus*.

1. Examine the slides of *Coprinus*. These were made from cross sections of the mushroom cap, which is called the **basidiocarp**. How does the hyphal organization of the mycelia in the basidiocarp compare to the organization of mycelia in the ascocarp of *Morchella* or *Peziza*? Is there evidence of septa? Look carefully before answering. Use digital images to illustrate your answers.
2. Now examine the edge of the basidiocarp. You will see oval or club-shaped cells that protrude above the surface. What is the name given to these cells? These are the cells in which karyogamy, meiosis, and spore formation occur and you will find them in all stages of development on the slides. Use the following terms to illustrate your digital images: **probasidium**, **metabasidium**, **basidium** and **sterigmata**.
3. In these slide preparations, it is difficult to distinguish between a probasidium and a metabasidium. What definitive criterion could you use to make this distinction? How many spores are produced by each cell? How does this number reflect the fact that these cells are the sites of meiosis?
4. Examine the external morphology of the living basidiocarps and obtain digital images with the digital camera. Label the following structures: **pileus**, **stipe**, **gills** or **pores**, **annulus**, and **scales**. Is the development of each basidiocarp **gymnocarpus**, **pseudoangiocarpus**, or **angiocarpus**? Explain how you made this determination.
5. Now carefully make a longitudinal section through the basidiocarp and obtain another digital image with the digital camera. Relate what you see to part D. Remove a piece of the gill, make a wet mount, find the structures listed in part B, and take digital pictures.

Activity 5: Field Trip: Powdery Mildews

1. Powdery mildews are the whitish mycelia found covering the surface of the leaves and sometimes the fruits of many flowering plants. If time permits, we will take a walk around campus to find examples of these fungi. Bring them back to the lab and observe them with the dissecting microscope, then carefully scrape the mycelia onto a glass slide, and make a wet mount. Look for small black dots among the white hyphae. These structures are the sporocarps. They are usually covered with various types of appendages, which are important identification characters. Obtain digital images of these structures and their appendages.
2. Now, using a pencil eraser, carefully apply pressure to the cover slip making sure not to break the cover slip. This will break open the sporocarp to release the sporangia. Based upon the shape of the sporangia and the number of spores, to what phylum do the powdery mildews belong? What type of sporocarp does this group have? Use digital images to illustrate your answer to this question.
3. Consult the "Key to the North American Genera of the Powdery Mildews" (Alexopoulus and Mims, 1979) to identify the species you have found. Include images of each species.

Literature Cited

Alexopoulos, C.J. and C.W. Mims. 1979. Introductory Mycology, 3rd edition. John Wiley and Sons, New York.

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About the Authors

Bruce W. Robart is an Assistant Professor of Biology at the University of Pittsburgh, Johnstown campus (UPJ). He received a bachelor's of science degree in Biology from the University of Akron, Akron, Ohio (1981) and a master's of science in Biology from the same institution in 1986. In 2000 he received a Ph.D in Biology from Illinois State University, Normal, Illinois. He has taught biology for non-majors at Wayne General and Technical College in Orrville, Ohio and since 2000 has taught General Biology, Plant Science, Local Flora, General Ecology, Conservation Biodiversity, and Life Sciences at UPJ. His research interests are in molecular and morphological systematics and population genetics.

Kimberly A. Ziance is biology laboratory instructor at the University of Pittsburgh at Johnstown (UPJ). She teaches laboratory courses for General Biology, Ecology, Anatomy and Physiology, Cell Biology, and Animal Physiology. She is a magna cum laude graduate of UPJ with a Bachelor of Science degree in Secondary Education/Biology. She was the recipient of the 2004 *Edward A. Vizzini Teacher of the Year Award in the Natural Sciences* at UPJ.

Melonie J. Dropik is an Assistant Professor in Science Education at the University of Pittsburgh at Johnstown. She received her Ed.D. in Instruction and Learning from the University of Pittsburgh (1999). Melanie's research interests include strategies for promoting reflective practice in student teacher preparation and in the practices to best teach science to nonmajors at the undergraduate level.

Appendix A: Student Assessment of Activity

In the following section, we have compiled selected replies to an evaluation sheet that lab students were asked to complete after they submitted their final notebook project to the instructor.

Group Project Evaluation – Digital Notebook

Please completely answer the following questions. Your responses will help to improve this course project.

1. What specific skills did you acquire while working on this project? Please list at least 2 skills.
   - I learned how to use digital microscope/computer/microscope software.
   - I learned how to use Power Point.
   - I earned how to use identification keys.
   - I learned how to find the specific structures that I needed while taking pictures with a camera and digital microscope.

2. Did you have any difficulty using the digital camera, digital microscope, or computer software? If you answered yes, please list and explain the problems that you encountered.
   - At first, using the digital camera and software was a little difficult – after a while I had no problems with the equipment
   - The digital microscope is my new favorite lab instrument.

3. Did the instructor give you specific directions on how to develop and complete your digital notebook? If you answered no, what information could the instructor give to you to assist you in completing this assignment?
   - All students surveyed answered "yes" to this question.

4. Do you feel that the time required to complete your digital notebook was appropriate for this type of course? Were you provided with sufficient time in lab to complete this assignment?
   - In general, most students surveyed felt that the time required to complete the project was appropriate for the lab course.

5. What did you dislike about working in a group to complete your project? Please list at least 2 dislikes.
   - Depending upon others to complete the assignment.
   - Group organization is difficult at times.
   - Group decisions concerning font and colors took a little too much time in the beginning of the project.
   - Compromising to get the work done was not easy.

6. What did you find beneficial about doing this digital notebook project?
   - I got a better understanding of the course material.
   - I learned parts of the organisms by labeling my digital images.

- The project is an excellent summary of what we learned in lab about different families and their characteristics.
- The project made learning the lab material easier.
- This project allowed me to work with software that I have never used before.
- I learned a great deal of information about the computer and technical equipment.

7. What suggestions would you make to improve the digital notebook project?

- Students should label the pictures as soon as they take them.
- Students need to have good time management skills.

The following is a comment that was written by a student upon completion of her digital laboratory notebook:

"Creating a digital laboratory notebook was extremely beneficial to my learning experience in many respects. Through the use of the digital microscope, I was able to capture images and observe specimens efficiently and with great ease. As a result, I found myself focusing upon the lesson and material with little time spent waiting for results or drawing pictures. Most importantly, I was able to recall information learned in previous labs easily with the aid of digital photographs.

Compiling my digital photographs along with descriptions and labels into a digital notebook not only proved beneficial to my success within the lab, but has also provided me with a detailed and well organized reference to plant biology."

Appendix B

A variety of digital microscope set-ups are available in all price ranges:

- Simple – This set-up consists of a digital camera attached to the ocular of a light microscope. The digital camera can be hand-held against the ocular or various camera-to-ocular adapters are available depending on the make and model of the camera and microscope. Approximate cost = \$500 to \$800 (quality digital camera) and \$50 to \$300 (adapter).

  Websites for suppliers of various configurations of camera-to-ocular adapters:
  http://microscopeworld.com/digital/nikon-coolpix.htm
  http://www.microscope-store.com
  http://www.thales-optem.com
  http://zarfenterprises.com

- Basic – This set-up is comprised of a digital video camera connected to the ocular of a light microscope with an adapter. Various adapters are available depending on the make and model of the video camera and microscope. A computer interface is also required to capture the images into the computer. An interface can consist of an external video capture device or an internal video capture board that must be installed in the computer. Electronic stores such as Circuit City or Best Buy sell these devices. Approximate cost = \$1000 (video camera), \$50 to \$100 (adapter), and \$100 to \$200 (capture device).

Websites for supplier of video-to-microscope adapters:
http://www.thales-optem.com

- Integrated – This system combines a light microscope with a digital imaging device that includes a computer interface. Imaging software is usually supplied with the digital microscope. We used Motic Digital Microscopes for our workshop, which are sold under a variety of names. Carolina Biological Supply Company sells them under the Wolfe brand name. The models we used for this workshop are as follows under the Wolfe brand name:

  1) DigiVu CVM Microscope, WC-59-1275: stereo compound microscope; 4x, 10x, 40x, & 100x oil objectives; 10x eyepiece; mechanical stage; Abbe condenser; Motic Images 2000 Software; $1400.

  2) DigiVu CVM Stereomicroscope, WC-59-2015: stereo dissecting microscope; 10 to 40x zoom magnification; 10x eyepieces; dual illumination; Motic Images 2000 Software; $1500.

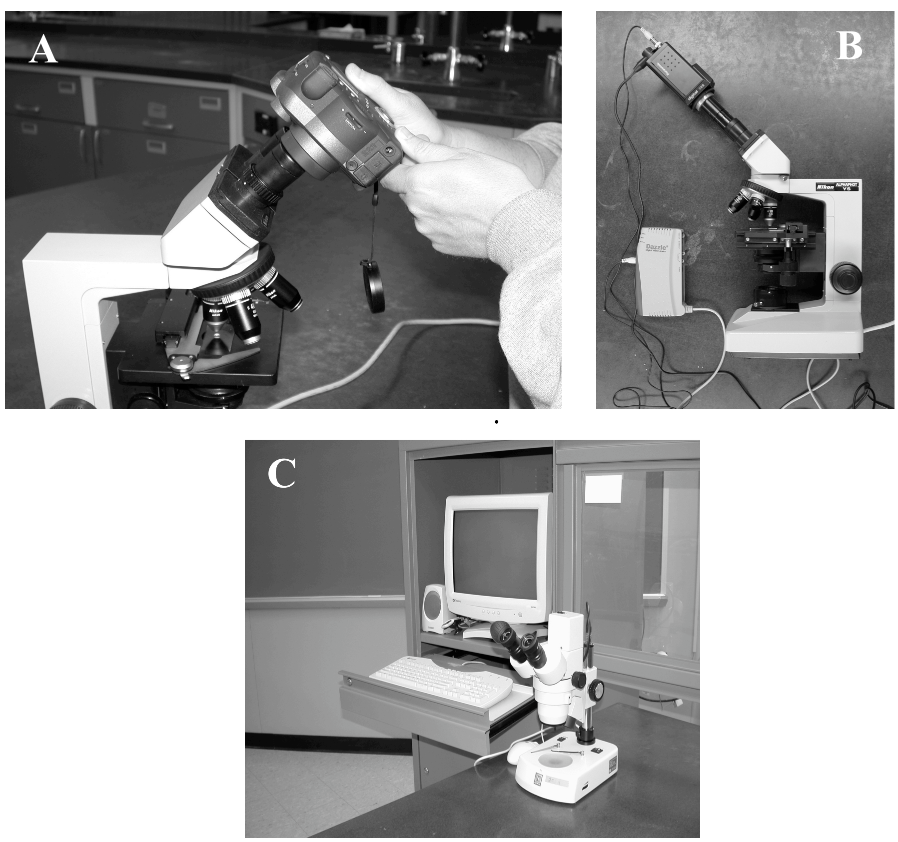

Figure 1. Types of digital microscope set-ups. A: simple, B: basic, C: integrated.