Conversion Immersion, Version 2.0: Working Together to Create Investigative Labs

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Abstract: This workshop built on the success of the first "Conversion Immersion" in 2004. The objective was to provide a forum for instructors to convert traditional "cookbook" laboratories to a more investigative format. This paper summarizes some of the ideas generated in the workshop, which included labs on the following topics: macromolecules; diffusion and osmosis; microscopy; cell structure; metabolism; photosynthesis; isolation of DNA; DNA structure and function; genetic analysis of dihybrid corn; cat genetics; phenotypic variation; Hardy-Weinberg equilibrium; invertebrate diversity; plant cells and tissues; angiosperm reproduction and seed germination; habitat preference of *Artemia*; community ecology; and aquatic food web interactions.

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Introduction

Biology educators have recognized the importance of investigative laboratories since at least the 1960s (Holt et al., 1969), and examples of tools for creating investigative labs are available in the literature (Sundberg and Moncada, 1994; Crandall, 1997; Volkmann and Abell, 2003; French and Russell, 2006). Nevertheless, many contemporary laboratory activities retain the traditional "cookbook" format in which students follow a prescribed set of instructions intended to produce a single desired outcome.

Part of the reason for the persistence of cookbook lab activities may be that instructors lack ideas. The lab activity may be outside the instructor's area of expertise, or the instructor may not be able to imagine a scenario that will spark students' interest. The objective of the first Conversion Immersion major workshop, held at the 2004 ABLE conference, was to provide a forum for instructors to work together to generate ideas for modifying specific, cookbook labs to a more investigative format (Hoefnagels and Walvoord, 2005). This paper describes the ideas that emerged from the second Conversion Immersion workshop, which followed a format nearly identical to the first.

Workshop methods

Forty-five workshop participants submitted 20 cookbook labs to us before the workshop. We organized the labs into groups of related activities. On the day of the workshop, after an explanation of our purpose, we divided the participants into groups of two to four and assigned each group a set of labs. Although most labs were considered in only one of the two workshop sessions (morning and afternoon), a few of the labs were discussed in both. The participants spent about half of the workshop working in their groups, brainstorming and summarizing their ideas for making the labs more investigative. Then each group reported its ideas to the rest of the workshop participants. The summaries listed here represent a compilation of notes we made during the oral presentations and written notes that each group submitted.

Results of workshop sessions

1. Macromolecules

Original procedure: Students use Sudan test for measuring the presence of lipids in water, glucose solution, and vegetable oil. They also use Benedict's reagent and iodine to test for the presence of mono- and disaccharides and starch in solutions containing water, glucose, starch, onion juice, and potato juice. And they use Biuret reagent to test for the presence of proteins in water, albumin, and starch solutions. They use the same reagents to test for the presence of each macromolecule in unknown solutions.

Morning group

Group suggestions: In a first exercise, students could bring in the food of their choosing, test for each type of macromolecule, and compare to a food known to have all three types of macromolecules. They could also compare to their own predictions and/or the nutrition label.

In a second exercise, students could move through the stages of digestion. For example, each group could be a different location in the digestive tract (the mouth, stomach, and small intestines), using enzymes (amylase, protease, lipase) and appropriate environmental conditions to report on which components of food are digested where.

A lively discussion followed this group's presentation.

- One participant suggested preparing a series of food extracts (e.g. potato, lima bean) and asking students to determine which macromolecules are present. Follow-up questions could include "Why do all foods yield a positive test for protein? Why is starch present in only some foods?"
- Another participant suggested a scenario in which a baby food manufacturer is considering possible additives. Given a range of unknown foods, which would be the best high protein supplement?
- Students could be asked to figure out which enzyme is which (instead of figuring out which molecules are present in which food).
- Instructors could prepare a series of pre-digested cheeseburger extracts, give each group one, and ask, "Where this came from in the digestive tract and how do you know?"
- Perhaps there is a way to tie these techniques to testing for specific allergenic proteins or carbohydrates.
- Another possible scenario would be to give students a budget (say $100) and ask them to determine the composition of a food. If each test costs a certain amount of money, which group gets the most information for the least amount of money?

Afternoon group

Group suggestions: Students are told how to use the reagents, but not which macromolecules each tests for. They can also be given known solutions of macromolecules, and then ask students to figure out what each reagent tests for. Once they have that information, they can test for the macromolecules in different types of food or nutritional supplements. Or, in a more advanced lab, students could use standard curves to quantify the amount of each macromolecule in each type of food (e.g. different types of cereal, different grades of milk, different types of fruit).

2. Diffusion and Osmosis

Original procedure: In the first investigation, students compare diffusion rates of potassium ferricyanide and methylene blue in agar to determine the effect of temperature and molecular weight on diffusion. In the second investigation, students use dialysis tubing bags and solutions of different syrup concentration to measure the rate of osmosis. In the third and fourth investigations, students apply salt solutions to sheep red blood cells, carrots, and *Elodea* leaves to determine the effect on the appearance of the cells.

Group suggestions: The group suggested combining the four investigations into three and removing the instructions for how to carry out each experiment. For diffusion, for example, the instructor could ask students to determine which characteristics affect the rate of diffusion. Students

would have access to agar plates, ice baths, hot plates, and a variety of dyes of known or unknown molecular weight. For diffusion, students could be asked to set up a system that demonstrates the movement of water, using materials such as starch, iodine, syrup, and milk. The third question would be, "How does osmosis affect living cells?" Students could be provided with red blood cells, plant cells, protists, and solutions of varying concentrations. Perhaps they could use the cells to determine the concentrations of solutions, or they could place eggs in solutions and describe what happened. Afterwards, students could brainstorm on applications to everyday life. For example, they could be asked to present to the class one detailed description of an osmosis or diffusion event.

In follow-up discussion, participants suggested using solutions of different concentrations to demonstrate the difference in the composition of *Elodea* and seaweed. Alternatively, students could be asked to find a way to affect the rate of diffusion or osmosis, or asked to measure the rate of action of the water vacuole in *Paramecium*.

3. Using Phase Contrast Microscopy to Measure Flagella in *Chlamydomonas*

Original procedure: The purpose of this lab is to help students become familiar with the microscopes. During the first part of the lab, students review microscope set-up (brightfield and phase contrast), calibrate eyepiece rulers, and discuss how to calculate specimen sizes. Then students measure the regrowth of flagella in a deflagellated culture of *Chlamydomonas*, both in pure culture medium and in culture medium containing a small amount of a drug. Finally, students to prepare a slide of fresh bull sperm, measure the cells, and observe how they swim in comparison to *Chlamydomonas*.

Group suggestions: The group suggested creating a scenario such as a chemical spill of cycloheximide or colchicine. Students can answer, "What is the effect of unknown chemicals on the regrowth of flagella?" They might also be asked to recommend whether or not to clean up the chemical spill. Students should be expected to develop their own data tables and procedures for measuring flagella length. Next, the instructor can pose a question allowing students to investigate/compare the flagella of *Chlamydomonas* and bull sperm. The question should somehow address the comparison of plant versus animal flagella structure. After completing the lab, the instructor can ask students questions such as: What microscope skills they had to know to perform the lab? What would you have liked to know before starting? What questions do you still have and where would you go next with this project? How would you develop a male birth control method? Could you use cycloheximide? How do female spermaticides affect sperm movement?

This *Chlamydomonas* lab is for cell biology students, but most introductory labs also teach the use of the microscope. To make these labs more investigative, instructors could provide labeled pictures of microscopes (http://www.udel.edu/biology/ketcham/microscope/) and have pairs of students determine the functions of one or two parts through investigation. The group also suggested replacing the classic "letter e" and "crossed thread" slides with slides depicting threads or hairs from a crime scene. Students could also estimate cell sizes and be asked, "Which is the largest cell?" Overall, the group recommended using slides with easy-to-find, slow-moving specimens that are relevant to student lives. The students might also be presented with a real-world problem like an unknown pollutant or a red tide and be asked to determine what is occurring.

4. Cell Structure

Original procedure: Students use the microscope to estimate the size of cells, observe wet mounts of human cheek cells, and observe *Anabaena*, another bacterial specimen, an archaeon, *Paramecium*, *Elodea*, *Sordaria*, and another human tissue.

Group suggestions: Give students several prepared slides representing each domain and kingdom. Have the students construct a dichotomous key (using quantitative measures) to distinguish among domains and kingdoms. Then give the students an unknown cell associated with an interesting mystery – perhaps the organisms is causing a crop to fail or fish to die or threatens human health. The students should identify the cell using the dichotomous key constructed by their group or a different group. To reinforce the purpose of stains, students can be given a selection of stains and asked to determine which structure or molecule is tagged by each.

Another idea is to look at cell-cell interactions (like *Azolla/Anabaena*, bacterial cells scraped along with human cheek cells, mycorrhizae). Have students collect data to investigate whether there are any patterns to the size or shape of the participants. Yet another option would be to find out how scientists originally discovered the functions of certain organelles and use that original research to build a case study.

In follow-up discussion, participants suggested other scenarios. For example, "If you were designing a new organelle, what would it look like, how would it work, and where in the cell would it be?" Or students can play the "cell doctor" game. That is, a cell might report, "I'm tired all the time, doc, what's wrong with me?" Students would have to decide which organelles are not working.

5. Fluorescent Detection of Cytoskeletal Proteins in Cultured Fibroblast Cells

Original procedure: Students use indirect immunofluorescence to label microtubules green, direct fluorescence to label microfilaments red, and Hoeschts fluorochrome to label the cell nucleus blue. The cells are mammalian fibroblasts growing on glass coverslips.

Group suggestions: After the students learn the technique, they could follow up by working with different cell lines. For example, students could be given cells described as the results of biopsies, and students would have to determine whether each cell type is cancerous. Perhaps they could also perform other tests to further characterize the cell lines. Alternatively, students could treat the fibroblasts with different cancer drugs and observe the effects on the cytoskeleton.

6. Sugar Metabolism in Yeast

Original procedure: The experiments in the original lab require students to determine the effect of ethanol on glucose metabolism in yeast (via a dose-response experiment provided in "cookbook" format). The idea is to teach students about glycolysis and subsequent aerobic and anaerobic metabolic pathways.

Group suggestions: The group suggested a scenario in which students have been hired by the biofuels division of a petroleum company to optimize the efficiency of production of ethanol (a biofuel). They must consider both the production rate and the final concentration of ethanol. Students have access to water baths at various temperature, solutions with pH from 4.0 to 10.0, solutions with known concentrations of ethanol, and other chemicals that might influence enzyme

activity. An alternative question would be to ask students to determine why the concentration of ethanol in wine is no greater than 10-12%.

7. Photosynthesis

Original procedure: This six-part lab includes paper chromatography of photosynthetic pigments, observing the absorption spectrum of spinach chlorophyll, observing the fluorescence of chlorophyll under UV light, determining whether electron transport requires light, measuring CO_2 uptake during photosynthesis, and observing starch storage/production during photosynthesis.

Morning group

Group suggestions: The students could try to answer the question, "Which light condition is best for photosynthesis?" They could use DCPIP reduction, CO_2 uptake (as measured by phenol red), and starch production by plants grown in different light conditions as measures of photosynthetic activity. The group also suggested adding a second experiment. The students could place *Elodea* plants in different light conditions (e.g. different wavelengths or intensities) or expose the plants to different CO_2 concentrations (using sodium bicarbonate as a CO_2 source). The dependent variable would be O_2 production.

Afternoon group

Group suggestions: This group decided to scale the lab down to focus on a couple of major questions. One would be: Why did plants develop so many photosynthetic pigments? This might lead students to some of the "subquestions" of how many pigments are in spinach or other leaves, whether pigments vary by biomes, or whether greener plants have more pigments than yellowish plants. The instructor would provide the spectrophotometer, chromatography supplies, and manometer and tell students how to use them. If they hit on the idea that each pigment absorbs a different wavelength, they could separate the pigments and use the spectrophotometer to figure out the absorption spectrum of each.

A second major question would be: How could you measure the rate of photosynthesis? This might lead students to the idea that starch and O_2 are measurable products of photosynthesis.

In follow-up discussion, participants mentioned that one easy way to visualize (but not extract) photosynthetic pigments is to mash a leaf directly onto skinny strips of chromatography paper with a ruler or the edge of a test tube or a quarter.

8. Isolation of DNA from Strawberries

Original procedure: Students are given a list of steps to follow to isolate DNA from strawberries.

Group suggestions: The group tried to think of ways in which students could use standard techniques to answer questions. For example, students could use this technique to visualize DNA, and the follow up with a forensics lab using mini-prep DNA. Or perhaps they could use PCR to find a gene of interest or do a restriction digest to look at variation in the genetic sequences.

Another idea was to combine this lab with other labs on biomolecules. For example, students could start with the question of what makes up a strawberry. Are water, DNA, starch, simple sugars, lipids, and protein present, and in what proportions? This lab could be extended beyond strawberries to other organisms: liver, kiwi, spinach, strawberry, the students' own cheek cells, frozen peas, or bananas. Perhaps students could use their results to make nutritional recommendations.

One other possible direction to go with this lab would be to develop a case study in which people are getting food poisoning, and epidemiologists think they have traced the source to strawberries. Students could be asked: "How would you know if your strawberries are from the contaminated source?" If you have different strawberry varieties, perhaps you could use DNA isolation to tell them apart.

9. From Gene to Protein

Original procedure: This lab covers DNA structure, replication, transcription, and translation. It begins with a case study about a child with sickle-cell trait. In Part I, students build a DNA model, then replicate the DNA. Then they "unzip" the DNA molecule and use one strand as a template for producing mRNA. The kit includes tRNA and amino acids so that students can also simulate translation. Students then answer a series questions (one of which returns to the case study described at the start of the lab). In Part 2, students observe the temperature-dependent production of the toxin prodigiosin by the bacterium *Serratia*.

Group suggestions: For Part 1, the group suggested focusing more on the case study. Instructors could begin by showing students two slides, one of sickled blood cells and one of normal blood cells. Then instructors could ask students, "What similarities and differences do you see between the cells? What is the girl's condition? How does the shape of her cells explain her condition? Using gene therapy, how could we fix her, and why should the change you propose work?" The lab could even be extended to include pedigrees, or students could run hemoglobin A and S on an agarose gel to show evidence of different genotypes.

For Part 2, the group suggested using other systems, such as pGLO. For example, the students might be invited to make fluorescent water-balloons for a black-light party. Or they might be told about an artist who made a pGLO rabbit and asked to determine what to feed the rabbit to make it glow in the dark. After researching what regulates pGLO, students could design an experiment to identify substances that turn the gene on or off.

10. Genetic Analysis of Dihybrid Corn

Original procedure: Each student tallies the four phenotypes of corn kernels (purple smooth, purple wrinkled, yellow smooth, yellow wrinkled) from a sample of 64 kernels. The students then use Chi-square tests to compare the actual phenotypic ratios to the expected ratios for two independently assorting traits.

Group suggestions: The group reported that it was hard to make this lab more investigative because it is a demonstration of a well-known principle, without an inherent question. A computer simulation might allow students to manipulate heritable traits and breed as many generations as needed, or perhaps it would be best to replace this lab with a different type of activity altogether that would engage students in the inheritance patterns while also relating to their daily lives. For

example, students might be asked to match domesticated plants with their wild ancestors (and perhaps research the inheritance patterns).

11. Cat Coat Genetics

Original procedure: Students examine photos of cats posted on shelter websites and collect the name, sex, hair length, hair color (including white spotting), and fur pattern (tabby, solid, Siamese) for cats in warm- and cold-climate cities. They then tally the phenotypes, calculate allele frequencies for each gene, statistically analyze the data, and propose explanations for differences in allele frequencies between cities.

Group suggestions: The lab is already pretty investigative but could be extended to analysis of more traits. In addition, students could design experiments to test their hypotheses for the differences they observe. Finally, students might be directed to cat breeding or pedigree data in the scientific literature to discover for themselves the inheritance patterns of the traits under study rather than being told which alleles are dominant and recessive.

12. Phenotypic Variation

Original procedure: Students grow *Brassica rapa* plants from seeds in different conditions of light intensity. Two or three weeks after sowing the seeds, the students describe the plants from each treatment qualitatively: stem color (green, purple, white), petiole color (green, purple, white), and flowering and budding (yes or no). Students then analyze the data and speculate on the cause for the differences between the three varieties of plants.

Group suggestions: Tell students that the different plant varieties are genetically different, and then ask them to determine the role of the environment in producing variation. One scenario might be to say that farmers are trying to improve their yield of radishes (or fast plants). Given three genetically distinct varieties of the same species, let the students design their own experiments to test the effects of temperature, light, fertilizer, water, and other environmental parameters that might help the farmers achieve their goal.

13. Hardy Weinberg Equilibrium

Original procedure: Students are given a bag containing 100 beads ("gametes") of two colors ("alleles") and instructed to count the number of beads of each type to first determine the allele frequencies in the population. They then use the allele frequencies to calculate the expected genotype frequencies at equilibrium. Students then withdraw 50 pairs of beads with replacement to generate a population, compare the observed genotype frequencies in the population with the predicted genotype frequencies, and analyze the results with a Chi-square test.

Group suggestions: The group suggested giving the students a supply of beads of unknown number and asking them to demonstrate (a) a population that is NOT in Hardy-Weinberg equilibrium; (b) how the population will be at Hardy-Weinberg equilibrium within one generation in the absence of evolutionary forces; (c) the effects of violating each condition of Hardy-Weinberg equilibrium; and (d) that populations with the same allele frequencies can have different genotype frequencies.

In follow-up discussion, a participant remarked that it is useful to have students predict what happens to a population if alleles are in different proportions. It is possible to set up fruit fly populations and actually run the experiment, but it takes longer to do it that way.

14. Invertebrate Diversity

Original procedure: This lab is an introduction to six animal phyla (Cnidaria, Platyhelminthes, Nematoda, Mollusca, Annelida, and Arthropoda). Background information includes the relationships between body symmetry, germ layers, body cavity, motility, and lifestyle. Students observe and answer questions about preserved and live specimens of in each phylum. Students also construct a dichotomous key to shells from representative mollusks.

Group suggestions: The group suggested omitting the background information and rote memorization questions provided in the lab; they should find this information in their textbooks. Open-ended questions about the adaptive significance of each structure are good. Instructors could also let students use the Tree of Life (www.tolweb.org) website before coming to class to discover the phylogeny of each organism. Additionally, students could be given an organism that doesn't intuitively fit into any phylum and determine where it best fits.

15. Plant Cells and Tissues

Original procedure: Students use the microscope and draw organelles in an *Elodea* leaf, chromoplasts, raphides, druses, cystoliths, crystals of anthocyanins, parenchyma, collenchyma, sclereids, and fibers.

Group suggestions: The group suggested building a case study related to the crystals in plant cells. For example, suppose people stranded on a deserted island have been eating five types of plants. Which of them is causing the people to develop swollen tongues and throats? The instructor can guide the students to help them learn what to look for inside the cells and to discover that all plant cells are not identical.

16. Plant Structure

Original procedure: Students examine and answer questions about liverworts, mosses, and ferns. For the seed plants, students examine and answer questions about the anatomical features of roots, stems, secondary growth, and leaves.

Group suggestions: The group suggested using a "jigsaw" approach with five groups of four students. Each group would get a bag of plant parts taken from a different community, along with stains, slides, and razor blades. The objective would be to describe the types of plants in the community. For example, one group's bag might contain young tree twigs, leaves, herbaceous stems, and herbaceous roots (hardwood forest), whereas another might contain moss gametophytes and conifer needles (coniferous forest), and a third might receive grass stems, grass roots, and herbaceous stems and roots (grassland). Students become "experts" that teach fellow other students about "their" community. In-class discussion might include pictures of the whole communities so that students connect the plant parts with each habitat. It might also be possible to work in the structure and function of vascular tissue, the evolution of the different structures, and the constraints to plant size.

In follow-up discussion, participants suggested making a bag of evidence from a crime scene and asking students to figure out what habitat the crime victim was in. Or, to extend it to reproduction, students could use a jigsaw approach to learn the reproductive parts of different types of plants. This approach would require students to apply knowledge from their textbooks and/or an atlas of plant parts.

17. Plant Embryo Germination; Angiosperm Reproduction and Seed Germination

Original procedure: In the embryo germination activity, students apply glucose, gibberellic acid, and abscisic acid to seed embryos and measure the effects on embryo weight, shoot length, root length, and the number of lateral roots. In the angiosperm reproduction and seed germination lab, students sketch a gladiolus flower, decide if it is a monocot or dicot, sketch a snow pea, sketch monocot and dicot seeds, and use I_2KI to determine where starch is stored in a monocot and a dicot seed.

Group suggestions: For the embryo germination activity, students could design their own experiments to determine the effect of glucose and different hormone concentrations on embryo growth.

For seed anatomy, students could dissect unknown seeds and ask to predict whether the seeds are from monocots or dicots. They could then germinate the seeds in Petri dishes and see whether their predictions were correct the following week. They could also make wet mounts of seedling stems and roots and compare the anatomy of dicots and monocots.

For fruit anatomy, students could be given the definitions of the different fruit characteristics (e.g. fleshy, dry, dehiscent, simple, etc.) and then develop their own dichotomous keys for the identification of about 12 fruits. Groups of students could exchange keys and use them to identify unknown fruits.

For the parts of a flower, students could learn the parts of a typical flower and then examine other, atypical flowers. They could be asked to use the shape, color, smell, and other flower features to speculate on the pollinator. It may also be possible to develop a scenario in which determining the pollinator might be important, as in the case of a greenhouse grower or endangered plant.

18. Habitat Preference in *Artemia*

Original procedure: Students formulate hypotheses about the responses of *Artemia fransciscana* (brine shrimp) to gradients of temperature, pH, and light intensity. Each bench is assigned a different treatment. The instructions tell students how to set up the gradients in Tygon tubing, count the *Artemia* in each section of tubing, and analyze the data using the Chi-square test.

Group suggestions: Allow students to figure out how to set up the gradients, what data to collect, and how to organize and analyze the data. Each bench could choose a parameter to test (rather than assigning each group a different parameter). Additionally, the instructor might describe how to set up a simple, one-variable experiment but have students design experiments with conflicting variables (e.g. do *Artemia* prefer a certain light level over a certain pH?).

19. Community Ecology

Original procedure: Students study interactions between pairs of species (mutualisms, commensalisms, predator-prey interactions, and parasitism). They examine and sketch structures from several examples of prepared slides and live organisms.

Group suggestions: One approach would be to select just one interaction to study in greater depth. If the idea is to investigate the scope of ecological interactions, then develop a scenario in which a park director plans to apply pest control products. The students have been hired as consultants by a local environmental group to predict the effects of the products on biodiversity and species interactions. The class could evaluate the current species diversity at the location and determine what they need to know about each organism they collect (including how it interacts with other species). They could also choose one pesticide, predict which organisms would be eliminated, and predict the subsequent effects on the ecological interactions within the community.

20. Aquatic Food Web Interactions

Original procedure: The objective of this lab is for students to answer the question of whether total biomass in natural communities is regulated by phosphorus ("bottom up") or predation ("top down"). This lab uses 32-gallon trash cans filled with pond water and phytoplankton as simulated lake ecosystems. Then four combinations of "phosphorus" and "fish" treatments are applied in a 2x2 factorial design. After several days, each student group is assigned to sample and count zooplankton or phytoplankton, with optional measures of water quality.

Group suggestions: The instructor can set up the aquaria ahead of time and then ask students whether top-down or bottom-up effects control phytoplankton (or zooplankton) production. Students should be given access to all necessary equipment to carry out the experiments, but they must design their own experiments. In a more advanced class, students can figure out how to set up the tanks and design their own experiments (perhaps with the help of pre-selected journal articles with good protocols). Alternatively, instructors can assign each group to become "experts" on a particular component of the ecosystem.

Conclusions

The Wisconsin Program for Scientific Teaching (http://scientificteaching.wisc.edu/) has produced a handout entitled "Un-cooking the Lab." Among other skills, the handout proposes that inquiry-based labs should induce students to "think analytically and critically about experimental design," "experience the collaborative nature of science as they negotiate with peers and communicate their explanations," and "give priority to explanations based on evidence." As in the first Conversion Immersion workshop, the participants found creative ways to meet these criteria.

The participants suggested many different approaches to developing investigative labs, but the objective was nearly always to eliminate the certainty of one desired outcome. Many of the "converted" labs required students to discover background materials in their textbooks or in the scientific literature, ask their own questions, and design their own experiments. Some began with real-world questions relevant to student experiences, whereas others proposed involving students in games or contests. Some of the labs may lend themselves to a "jigsaw approach" in which students

become experts on one component of the lab and then teach their newfound knowledge to their peers. A related approach is to have students develop and share their own dichotomous keys. In all cases, the emphasis is on inducing students to think for themselves.

Although some labs are clearly harder to convert than others (Crandall, 1997), it is equally clear that most labs can benefit from an investigative approach. All of the labs considered in this workshop were improved as a result of the ideas contributed by the participants in this workshop. Often a very simple change improved the quality of the lab, leading to a more interesting and thought-provoking laboratory experience for the students.

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Converting labs from "cookbook" to investigative is rarely easy, yet the participants came up with creative and practical ideas in just a couple of hours. We gratefully acknowledge the participants in this second Conversion Immersion workshop for their enthusiasm and willingness to share. This workshop could not happen without you.

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- Fluorescent detection of cytoskeletal proteins in cultured fibroblast cells: Marilee Ramesh, Ed Hipkiss
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- Cat coat genetics: Jennifer Van Dommelen, Chuck Elzinga
- Phenotypic variation: Larry Blumer, Judy Guinan, Debby Luquette, Carol Sanders
- Hardy-Weinberg equilibrium: Jennifer Van Dommelen, Chuck Elzinga
- Invertebrate diversity: Karin Readel, Louise McBain, Chris Beck
- Plant cells and tissues: Kelly Bohrer, Natasha Woods, Lisa Cheung
- Plant structure: Darlene Panvini, Emily Boone, Miriam Ferzli, Judy Nesmith
- Plant embryo germination; angiosperm reproduction and seed germination: Steven Gabrey, Maggie Haag, Saphida Migabo, Kellie White
- Habitat preference of *Artemia*: Karin Readel, Louise McBain, Chris Beck
- Community ecology: Larry Blumer, Judy Guinan, Debby Luquette, Carol Sanders
- Aquatic food web interactions: Karin Readel, Louise McBain, Chris Beck

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