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CONVERSION OF TRADITIONAL OBSERVATION-BASED BOTANY LABS TO INVESTIGATIVE INQUIRY LEARNING

A Thesis
Presented to
The Faculty of the Department of Biology
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment
Of the Requirements for the Degree
Master of Science in Biology

By
Hajara Mahmood

August 2008

CONVERSION OF TRADITIONAL OBSERVATION-BASED BOTANY LABS TO INVESTIGATIVE INQUIRY LEARNING

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

All praise to the Almighty, the Creator.

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TABLE OF CONTENTS

Acknowledgements…………………………………………………………………iii

Table of Contents…………………………………………………………….………v

List of Tables………..……………………………………………………………...vi

List of Figures…………………………………………………...……………….……vii

Abstract………...………………………………...…………………………...…….viii

Introduction………………………………………………………………...………1

Materials and Methods……………………………………………………………...13

Results……………………………………………………………………………29

Discussion…………………………………………………………………………..33

Tables…………………………………………………………………………….42

Figures……………………………………………………………………………49

Appendix………………………………………………………………………….57

Literature Cited…………………………………………………………………104

LIST OF TABLES

Table 1: WKU Plant Biology and Diversity Lab Enrollment for Academic Years 2001-2007……………………………………………………………...…………………..42

Table 2: Student Grade Point Averages………………………………………………..…43

Table 3: Means for Score Distribution…………………………...……………………44

Table 4: Means and independent samples t-test across 11 labs for Group A and Group B…………………………………………………………………...……..45

Table 5: Means and independent samples t-test across traditional material for Group A and traditional & new material for Group B………………………………………..46

Table 6: Selected survey question : The labs we conducted in this course had the following effect on my learning…………………………………………………………47

Table 7: Survey responses for selected lab activities.
What impact did each of the following have on your interest for this course?................48

LIST OF FIGURES

Fig. 1: Example page from older edition botany lab manual used by Group A……..….49

Fig. 2: Example page from updated botany lab manual used by Group B…………..…..50

Fig. 3: Assessments for Group A and Group B……………………………………….51

Fig. 4: Student survey responses across 11 labs……………………………………52

Fig. 5: Student survey responses: challenging…………………………………...53

Fig. 6: Student survey responses: interesting……………………………………….54

Fig. 7: Student survey responses: overwhelming………………………………..55

Fig.8: Student survey responses: intellectually stimulating………………….……..56

CONVERSION OF TRADITIONAL OBSERVATION-BASED BOTANY LABS TO INVESTIGATIVE INQUIRY LEARNING

Hajara Mahmood August 2008 Pages: 107

Directed by: Heather M. Johnson, Lawrence A. Alice and Shivendra V. Sahi

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"Tell me and I forget, show me and I remember, involve me and I understand." - Chinese Proverb. Involvement in learning implies possessing skills and attitudes that permit students to seek resolutions to questions and issues while constructing new knowledge.

Low enrollment in Plant Biology and Diversity and upper level plant science courses has been noticed at Western Kentucky University. In addition, graduating students performed below the national average on the senior assessment examination in the area of botany content knowledge offered by WKU's Biology Department. This may be due to the fact that observation-based botany has been taught in a traditional way for biology majors at our university for many years. Traditional teaching methods include viewing prepared slides of plant sections, viewing live and herbarium specimens, and memorization of botanical terminology and illustrations. The goal of this study is to convert these existing traditional laboratories to investigative inquiry exercises without compromising the material covered by bringing observation-based labs into the twenty-first century.

Various teaching strategies including inquiry, problem-based, case-based, and hands-on learning methods were implemented. Each exercise was reshaped around a

central question or theme. These changes were expected to increase student learning and retention levels.

Traditional teaching methods were used with the control group, while contemporary teaching strategies were used with the experimental set of students. Traditional assessments and anonymous surveys were statistically analyzed. The results of my analyses suggest that the experimental students were more challenged, interested, intellectually stimulated, and less overwhelmed with contemporary teaching strategies and overall had higher learning retention demonstrated by their performance on assessments.

Moreover, I predicted that an investigative approach will encourage larger numbers of students to take this restricted elective sophomore-level course for biology majors and further their study in plant biology.

INTRODUCTION

"Tell me and I forget, show me and I remember, involve me and I understand." - Chinese Proverb.

The Need for Reform in Botany

A decrease in interest in the study of botany has been evident nationally through a reduction in enrollment of botany majors (both graduate and undergraduate), as well as a decline in post-secondary institutions offering botany majors or botany courses (Uno 2007). Even at the beginning of the twentieth century, scientists were noticing a decline in student interest in botany (Bower 1925), with explanations ranging from "dryness" of topic material, too specialized of material, no practical significance, or too much lecture (Hershey 1990; Tamir 1974).

Low enrollment in Plant Biology and Diversity (Table 1) as well as upper level plant science courses e.g., Plant Physiology, Plant Biotechnology, and Medical Botany has also been noticed at Western Kentucky University (WKU). Additionally, WKU's graduating biology seniors and graduate students scored below the national average on the 2003 senior assessment exam in the category of organismal biology (biology of plants, animals, protista, and fungi). In this category, 11 questions pertained to plant biology knowledge. Students scored below the national average for 7 of the 11 questions regarding botany content. The senior assessment offered by WKU's Biology Department consists of 100 questions modified from the Praxis Biology Content Knowledge 0230 practice test.

Observation-based botany has been taught in a traditional way for biology majors at WKU for many years, as it has at most universities. Traditional teaching methods include viewing prepared slides of plant sections, viewing herbarium and live specimens, and memorization of botanical terminology and illustrations. Although the traditional lab included some hands-on aspects, it lacked a conceptual framework to help students understand how plants could be used in scientific investigation. Furthermore, there is little emphasis on problem-solving or real-life applications.

New Pedagogy Methods

As early as 1969, the Commission on Undergraduate Education in the Biological Sciences claimed that "the best use of the laboratory in undergraduate instruction is to engage the student in the process of active investigation" (Holt et al. 1969). Holt and his colleagues emphasized the importance of investigative labs in "communicating the nature of biology as a branch of thought, not just as a collection of facts." This approach not only familiarizes the students with the scientific method, but also gives them experience with other aspects of the process of science, such as creativity, critical thinking, problem solving, collaborative work, and ownership of the experience (Phillips et al. 2007).

A growing number of teachers are realizing the value of new pedagogical methods such as inquiry learning, but few go to the trouble of incorporating it into their courses (Windshitl 1999). Many instructors shy away from new teaching approaches due to the amount of work and time required in preparations, however once the material is redesigned, lab exercises can be easily implemented into pre-existing curricula (Senchina 2007). Also, the benefits to student learning outweigh these initial costs to the instructor (Lord et al. 2007).

There is more literature published on the use of new teaching methods in biology classes at the secondary and even primary levels than at the postsecondary level (Colburn

2003). National Science Teachers Association (NSTA) discussed a finding that research universities are reluctant to embrace and implement proven teaching methods in science classrooms (Brainard 2007). NSTA (2004) recommends that all K-16 teachers encompass scientific inquiry in the classroom, which will help ensure that students develop a deep understanding of science and scientific inquiry.

The most widespread inclusion of contemporary education strategies has been in introductory science courses for majors and non-majors (McDaniel et al. 2007; Etkina and Murthy 2006; Ribbens 2006). Some upper level courses are inquiry-based by nature, for example, senior project courses; however, a few instructors teaching other types of upper level science courses are also beginning to apply inquiry-based methods (Lord et al. 2007). Courses with a more clinical slant have followed the lead of medical schools with the use of cases to teach the material (Delisle 1997). In the biological sciences, fields such as anatomy and physiology (Delisle 1997), microbiology (Prescott et al. 2002), general biology (Ribbens 2006), and molecular biology (Gubrium et al. 2003, Regassa and Morrison-Shetlar 2007), the use of case-based aspects is more evident. Botany is a great example in biology, in which contemporary teaching strategies are often not put into practice, but could benefit from this type of pedagogy.

Goals for Reform at WKU

The goals of this project is to redesign a botany lab section to see if contemporary teaching strategies benefit learning, application, engagement and interest amongst students taking our Plant Biology and Diversity Lab at WKU. Each lab activity is focused around a central theme or question. Investigative lab activities were included in weekly labs for Group B (experimental group), which offered students the opportunity to apply botany to real life as well as use technology in the classroom.

Redesigning botany labs may increase enrollment in BIOL 222 and 223 Plant Biology and Diversity lecture and laboratory, increase enrollment in upper level plant courses, including BIOL 400 Plant Physiology, BIOL 475 Medical Botany, and BIOL 496 Plant Biotechnology as well as increase scores on the Biology Department Senior Assessment Exam in the area of plant biology.

Educators have speculated that incorporating inquiry into a course will necessarily require the elimination of important content from the course (Hirsh 1996 and Windschitl 1999). The intention is to update existing traditional labs at WKU to investigative, inquiry labs without compromising the depth of material covered. We are replacing basic memorization with active investigation, participation, and problem solving. This form of learning challenges students as they have an opportunity to share information, demonstrate knowledge, and engage in independent learning (Alesandrini and Larson 2002).

Moreover, I predict that new teaching methodologies will encourage larger numbers of students to take this restricted elective sophomore-level course for majors and further their study in plant biology. This project includes methods involved in bringing observation-based labs into the twenty-first century, descriptions of revised labs, and analysis based on student grades and survey responses.

Contemporary Teaching Strategies Implemented

Involvement in learning implies possessing skills and attitudes that permit students to seek resolutions to questions and issues while constructing new knowledge.

Hanauer et al. (2006) stated that when students engage in inquiry and learn to integrate their ideas, they are prepared to apply what they learn in science classes to contexts beyond the classroom. This approach is referred to as constructivism, which is based on "the conception that we learn by relating new experiences to our prior knowledge; we construct new understandings based on what we already know" (Sherman and Kurshan 2005). Students gain interest and have a better understanding when they use the skills and knowledge they have learned in the classroom and apply it to activities or experiments. "Classrooms that are active, interesting, learner centered, focused on real life, are social and provide time to learn, allow frequent and facilitative feedback, and support both learning to be good learners as well as learning content have consistently been shown to be more effective with all learners," (Sherman and Kurshan 2005).

Various constructivist approaches were incorporated in modernizing the labs throughout the Plant Biology and Diversity lab manual including inquiry, case-based, problem-based, and hands-on learning. These methods can seem similar and are often not clearly defined in literature. Listed are pertinent descriptions of methods applied to this project.

Inquiry learning

Inquiry learning broadly includes science process skills and higher-order thinking skills, as well as abilities in questioning, predicting, explaining, and communicating findings (NRC 2000). Inquiry-based instruction allows students to engage in open-ended, student-centered, hands-on activities (Colburn 2003). National Research Council (2000) defines scientific inquiry as "the activities through which students develop knowledge and understanding of scientific ideas as well as an understanding of how scientists study the natural world." Educators think that they can either stress inquiry learning, using lots of hands-on experiences, or stress content knowledge, decreasing hands-on learning and proportionately increasing direct instruction (Robertson 2007). However, instruction is most effective when both teacher-centered and learner-centered methods are utilized (Sherman 2005). During each botany lab, students were presented material to be learned and then were made responsible for constructing their own understanding and completing investigative activities.

Inquiry learning engages students, which gives them a chance to get involved and to seek information by questioning. Three types of inquiry learning include structured inquiry, guided inquiry, and open inquiry. The majority of activities added to the lab used structured and guided inquiry methods, in which students were presented with a purposeful problem to solve. This is in contrast to open-ended inquiry, in which students solve a problem that has many possible answers and therefore, takes more time (McDaniel and Johnson 2007).

Structured Inquiry

In structured inquiry learning, the instructor usually gives students hands-on activities they are to investigate, and the methods and materials necessary for the investigation, but not the expected outcomes (Colburn 2003). Students are responsible for analyzing and interpreting data, discovering relationships, and making conclusions from the facts collected (Colburn 2003). All structured inquiry activities have a definite right answer that students are supposed to seek during the lab activity.

An example involved students constructing two experimental procedures on the topic of seed germination. They were given the task of contrasting growth rates as well as shoot and root development of *Brassica rapa* seeds with and without soil. This activity is very hands-on and has a definite answer students explore.

Students also investigated medicinal properties of plants. They were provided bacterial cultures to determine the strength and antimicrobial properties of garlic extract. Again, students are to seek precise answers for this activity.

Guided Inquiry

In guided inquiry learning, instructors only provide students with the problem to investigate (Colburn 2003). Students are responsible for figuring out how to answer the investigative question and make conclusions.

One example involved a case study on water contamination as students analyzed algae and cyanobacteria. Students were provided a problem to investigate while surveying lab content. As students worked in groups, they were responsible in making conclusions and answering investigative questions. This gave students a purpose while studying lab material. Applying botanical knowledge to a simulated, investigative case such as the water contamination issue provided inquiry-based learning in the botany lab.

Another example included an experiment on genetically modified (GM) foods. Students were provided all materials and instructions to test various food items; however they generated and interpreted whether their plant product was genetically modified based on results.

The next example of guided inquiry learning included a tree identification activity. Students worked in groups to identify different tree species using taxonomic skills in addition to investigating problems caused by invasive plant species.

This method was used in the classroom to provide students more structure and to prevent a loss of time to cover classroom material. In guided inquiry learning, students must be active in identifying the principles for themselves, in addition to the lecture provided by the teacher (Loertscher and Rosenfeld 2008). The teacher guides this process through explanation and student activity. Learning is more relevant and easier when students actively encode, store, and retrieve information on their own (Sherman and Kurshan 2005).

The advantages of guided inquiry learning includes the usefulness for learning new concepts and relationships and an effective means for integrating prior knowledge with new knowledge (Loertscher and Rosenfeld 2008). Educators can give students freedom to discover through exploration, yet guide the search so that students reach target knowledge (Robertson 2007).

Open Inquiry

This method gives students the entire freedom to conduct investigative science activities. Students determine the questions to investigate, procedures to address their questions, and data to analyze (Colburn 2003).

An example of open inquiry used in this lab included a forensic botany case in which students designed their own crime scene investigation. Students were given the task of creating and solving the case using knowledge of woody plants and botanical structures learned during the semester. In open inquiry activities, students must figure out everything on their own (Colburn 2003) allowing many possible answers.

Previous research has been done using open inquiry learning methods with a traditional biology major's botany course at Indiana University of Pennsylvania (Lord et al. 2007). Students took an active role by researching and preparing student-led discussions in the classroom; this method is known as Peer-Led Team Instruction (Lord et al. 2007). Students decided the content theme presented to their peers. The instructor provided lesson objectives for each group to make sure appropriate content was covered. Students also received an outline of pertinent information for each week in their course syllabus. Inquiry teaching was encouraged in that presenters structured their discussion with leader-directed questions, generated group responses to stimulate discussion, or used discovery scenarios (Lord et al. 2007).

Case-based learning

Case-based learning allows students to explore and apply their knowledge to real life situations as well as collaboratively analyze and solve problems (BioQuest 2007). According to the American Association for the Advancement of Science, students are recommended to work in teams to investigate and come up with solutions to problems posed by the course professor (Varma-Nelson et al. 2005).

The case illustrates the theory, presents the results of an experiment, or challenges students to explore a problem in search of a solution or solutions (Ribbens 2006). Cases can work effectively with hypothesis development, research design, data analysis, and the hypothesis reevaluation pieces of the scientific method (Ribbens 2006).

Examples included are a water contamination case and forensic botany case. Both cases allowed students to seek solutions to real-world problems and approach them collaboratively using botanical knowledge and processes. Learning with cases puts the learners more in control of the problems studied and the resources used than most other types of learning (BioQuest 2007). According to the National Research Council (NRC), what makes learning effective is the application of what is learned (NRC 2000).

Problem-based learning

The Buck Institute for Education (BIE) defines project-based learning as "a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks" (BIE 2002). Problem-based learning is often associated with medical schools, where students work together on medical cases (Colburn 2003). This learning method usually requires students to create solutions to real-world problems. This approach helps students develop critical-thinking and problem-solving skills, while learning basic science concepts (Colburn 2003).

For example, this technique was implemented as students were introduced to plant cells and tissues. Students explored the topics of phytoextraction and phytoremediation to understand their roles in removing toxins, heavy metals, and materials from soil. Students were able to apply plant structures being studied with current research being done at WKU.

Problem-based learning was also used during the experiment on genetically modified foods. Students were able to make a conclusion that a large number of food items derive from genetically modified plants. Various topics including ethics, solutions to world hunger, and producing high quality fruits and vegetables were briefly discussed.

These problem-based learning activities gave students a chance to develop questions and investigate on their own, as well as make real-life applications. Many times, students memorize material but will not fully understand or be able to use the information. Problem-based learning provides discovery skills, which helps students internalize learning and leads to greater comprehension (Delisle 1997).

Hands-on learning

Rutherford (1993) describes hands-on science as "having students 'manipulate' the things they are studying and 'handle' scientific instruments. In a more general sense, it seems to mean learning by experience."

The majority of lab activities for this course consisted of hands-on learning; however, there were three additional exercises that exclusively consisted of this practice including thin-sectioning of stems, spore growth and development, and seed germination. During the thin-sectioning activity students created their own sections of plant stems, viewed them under the microscope, and compared them with prepared stem sections. This activity gave students an appreciation for prepared slides viewed during the semester. The next examples on spore development and seed germination also comprised practical exercises, allowing students to set up experiments and observe plant development.

When students are engaged in learning they also show more interest. " It is only their own experiences that will lead them to the conviction that inquiry and reasoned argument offer that most promising path to deciding between competing claims, resolving conflicts, solving problems, and achieving goals," (Kuhn and Dean 2004). The students we educate must acquire basic science knowledge that is better retained, retrieved, and later used in real-life applications (Barrows 1995).

By engaging students as investigative learners, I hope that the new teaching methods encourage students to have greater interest in the material as well as retain more information. Students will extend their understanding through drawing, organizing, observing, and investigating. “Investigation changes ourselves and our perspectives on science in ways that are enabling, for learners to act, research and question on their own, to learn something new” (Cavicchi and Hughes-McDonnell 2001).

MATERIALS AND METHODS

Two BIOL 223 Plant Biology and Diversity labs were taught during the 2007 Fall Semester at Western Kentucky University (WKU). Twenty-two students registered for BIOL 223 Plant Biology and Diversity lab as a restricted elective course. All students enrolled in BIOL 223 were also in the same BIOL 222 Plant Biology and Diversity lecture session. Traditional teaching methods were used with Group A (control group), while an investigative approach was used with Group B (experimental group). The small number of students (22) in these two sections is due to the fact that BIOL 222 and 223 are no longer required courses for all biology majors at WKU. The enrollment has effectively been reduced to 25% of previous years.

Traditional teaching methods included the use of an older edition botany lab manual (Dillard 2004), brief lecture to introduce new content, examination of microscope slides, preserved and living specimens, drawing, and labeling black and white figures. Microscope slides comprised cross-sections, longitudinal sections, and whole structures. Group B received the same introductory lecture, examined the same slides and specimens however, new inquiry lab activities and a modified lab manual were incorporated. This manual contained color photos and images similar to the specimens they were viewing in class to make labeling and recognition easier. Additionally, experiments, case studies, and extra activities were incorporated into various labs. Specific laboratory exercises and changes were added in each lab as described:

<u>Group A- Control Group</u>

Group A was taught on Tuesdays from 12:30 – 2:30 p.m., with 10 students using traditional teaching methods. Intended outcomes for the course included a summary of cyanobacteria, algae, and plants with an emphasis on anatomy, morphology, development, and evolutionary adaptations.

Group B- Experimental Group

Group B was taught on Thursdays from 12:30 – 2:30 p.m. with 12 students and incorporated inquiry and investigative teaching methods. All content covered in Group A was also covered in Group B.

Following were the premises for changes made in Group B:

- Students observed macroscopic and microscopic organisms and plant structures and made drawings as before; in addition, colored pictures of selected organisms and plant structures were provided for students to label (Fig. 2).
- Each lab focused on a central question, theme, or experiment to make the study of botany more relevant and interesting.
- Example exercises consisted of a tree identification assignment and survey of invasive plants, thin-sectioning of plant stems, case studies on algae and cyanobacteria and forensic botany, investigation of phytoextraction and phytoremediation, a growth lab, experiments on fern spore germination and development, genetically modified foods, seed germination using Wisconsin Fast Plants™ (Carolina Biological Supply Co., Burlington, NC), and medicinal botany.

Assessment:

The methods of assessment used in these labs included traditional objective quizzes and exams and written lab assignments. The grading scheme for both labs comprised of 10 quizzes (10 points each), 11 lab assignments (10 points each), midterm and final exams (100 points each), and an extra credit opportunity (10 points).

Pages in the lab manual were graded weekly for both Group A and B for points on lab assignments. The older edition lab manual included space for sketching and labeling, however the figures were antiquated. The new manual retained some sketching and incorporated modern figures from the adopted textbook (Raven et al. 2005) for labeling as well as experiments, case studies, and investigative activities.

Students in both labs completed the same weekly quizzes which contained material from the prior and current week. Quiz questions were identical for both labs. Two major exams (a midterm and final) were designed to assess student learning. Each exam consisted of a practical portion worth 75 points and a written portion worth 25 points. Students in both labs received the same practical and written exam questions and were only tested on traditional material.

Both labs were offered an opportunity to volunteer a few hours of their day at Lost River Cave and participate in an invasive plant removal project. Students were offered 10 extra credit points and were able to schedule their hours during the weekday or weekend.

Lab 1: Introduction to Classification and the Microscope

This lab introduced students to classification and the microscope. Students in both labs participated in a classification activity. This activity required students to work in groups to create their own classification system and taxonomic key based on line drawings of shapes with various characteristics (e.g., circles, lines, squares) provided to them on a sheet of paper. Students cut out the drawings and grouped them accordingly.

After each group completed their key, students from the other groups were challenged to figure out the diagnostic traits. This allowed students to become familiar with taxonomic keys, classification, and demonstrate that classification is a human construct and thus variable.

During the second half of this lab, students followed instructions provided in the lab manual to familiarize themselves with the microscope. The microscope was used frequently during the course to view various microscopic-sections of plant structures. Students in Group A viewed a few sample slides to acquaint themselves with the microscope, while Group B participated in an additional activity on thin-sectioning. Students in Group B picked various plant stems from the butterfly garden located outside the biology building and created their own cross-sections and viewed them under the microscope. This made the lab more interactive and allowed students to understand and appreciate slides they viewed during the semester.

Lab 2: Woody Plant Identification

The objective of this lab was to familiarize students with woody plant identification using taxonomic keys. This lab gave students the opportunity to go outdoors and identify trees based on morphological features. Both Group A and Group B attended a field trip to Lost River Cave located in Bowling Green, KY. Students were provided a lab packet with a taxonomic key for identification of some common trees, as well as a tree identification booklet on trees found in the eastern and central U.S. (NADF 2007).

Students in both labs were given the assignment to properly identify at least five trees and to bring back leaf samples. Students in Group B were also given the incentive of identification plaques being placed on the trees they properly identified. Students in Group B received string, permanent markers, laminated tags, and a map of the Lost River Cave trail to tag the trees. Digital cameras were also provided for students in the experimental group to take pictures of the trees they identified. In addition, a staff member from Lost River Cave gave a short presentation on invasive plant species commonly found in Kentucky and described the effects they have on native plants. During this time, the staff member gave a quick tour of the historic preservation and pointed out invasive plants.

Students in both labs had an opportunity to receive extra credit by participating in a community service project on the removal of invasive plants at Lost River Cave. Students participated in this activity during their own scheduled time. This activity was offered to get students involved with the community.

Lab 3: The Algal Groups-Oxygenic Photoautotrophic Prokaryotes and Protists

Algal groups and cyanobacteria were surveyed as Group A and B observed various prepared slides, herbarium specimens, and wet mounts of living cultures. Students made sketches and labeled figures in their lab manuals. Students in both labs also made observations of bioluminescent dinoflagellates (*Pyrocystis fusiformis*) to learn how and why they produce light (Haddock 2004).

Group B used similar techniques as Group A, but with a new purpose. The experimental lab was centered around a case study on water contamination (Jewell 2007 and WHO 1999). They were given the task of identifying which type of algae or cyanobacteria caused the water to become contaminated. At the end of the lab, a few questions were provided for students to answer. Also, a guide on water quality was handed out to aid students with the case (CRC 2008). By adding this study to this lab, students were given a purpose to study the algal groups without making the material overwhelming.

Lab 4: Introduction to Plant Cells and Tissues

This lab introduced botany students to plant cells and tissues. The material in this lab is very important as it introduced basic plant structures students observed throughout the semester. Students in both labs viewed various slides of leaf, stem, and root sections as they labeled figures and drew appropriate plant structures in their lab manuals. Students learned the roles of plant cells and tissues, including the process of photosynthesis and transport of water and nutrients to various regions of the plant. To bring relevance to this lab, the topics of phytoremediation and phytoextraction were introduced to Group B. The microscope slides of plants cells and tissues viewed are structures that play roles in removing toxins, heavy metals, and minerals from soil. Students were able to make connections between plants, environmental improvement, as well as using plants to collect materials of interest, such as gold. At the end of lab, students worked in groups and answered investigative questions listed in their lab manuals regarding these techniques used in plant biotechnology. A few articles (Sahi et al. 2002; Tack et al. 2005) were provided to help students answer the questions. Students also had the opportunity to further research these topics to aid them on the assignment.

Lab 5: The Non-Vascular Embryophytes-Bryophytes

Students in both labs studied non-vascular plants known as bryophytes. Slides and plant specimens were viewed during this lab. Students in Group A and Group B observed live and preserved mosses, preserved liverworts and hornworts, and dissected a mature moss sporophyte using dissecting microscopes to observe specific plant structures such as seta, calyptra, capsule, peristome, and operculum.

Those in Group B set up an experiment on fern spore germination and development for Lab 6 (Eichhorn et al. 2006). Students were provided Petri dishes with plant nutrient agar to culture spore growth. Spores from the sori of a leptosporangiate fern were collected and diluted in a flask containing deionized water. Students poured and spread 1 mL of the solution containing fern spores onto their nutrient agar plates using aseptic technique. Students then inserted wet paper towels and their Petri dishes into zip lock bags and placed them under a fluorescent light source located in the classroom. Students observed prothallial growth to understand the process of plant cell cultures. Students were able to observe gametophyte development after eight weeks.

Addition of Genetically Modified Organism (GMO) Experiments to Labs 6-8

The topic of plant biotechnology was incorporated in Group B, as students in this group conducted an experiment on genetically modified organisms over a course of three lab sessions. A copy of the Biotechnology Explorer GMO Investigator Kit student manual by Bio-Rad was handed out for each student, providing background information, instructions, tables, and figures (Bio-Rad Laboratories, Inc. 2007).

Students in Group B used experimental techniques from the Bio-Rad GMO Investigator Kit to test for the presence of two different GMO-associated DNA sequences present in most (>85%) of the genetically modified crops that are approved for distribution worldwide (Bio-Rad Laboratories, Inc. 2007). This kit gave students an opportunity to do a complete investigation and to assess the validity of their results. Part one was conducted during Lab 6 and consisted of students selecting food items from the grocery store and extracting DNA from various food samples. Part two was performed during Lab 7 to conduct PCR (Polymerase Chain Reaction) and amplify DNA sequences for their negative control, positive control, and experimental food item. Part three was completed during Lab 8, in which students performed agarose gel electrophoresis for all their samples to view DNA fragments. These samples were compared with a DNA standard to determine the presence or absence of the amplified GMO sequence (Bio-Rad Laboratories, Inc. 2007).

Lab 6: Cryptogamous (Non-Seed Producing) Vascular Plants

Cryptogamous vascular plants were studied, which includes non-seed producing plants such as club moss, horsetail, and ferns. Students in both labs viewed several slides, herbarium specimens, and live plants. They recognized specific plant structures unique to each group. Students in Group B were given the first half of the lab period to view the material on cryptogamous vascular plants. The second half of the lab period was used to begin part one of the experiments on genetically modified foods. A brief introduction on genetic modification in foods was given before students started the experiment.

Students in Group B worked in groups on the experiment with the selected food item of their choice. All materials were provided to conduct this experiment, which included soy beans (positive control), mung beans (negative control), sterile graduated disposable pipettes, mortar and pestles, screw cap tubes, distilled water, InstaGene, and hot water bath. Each group followed appropriate directions to extract DNA from their food samples. Students were directed to grind their soy beans, mung beans, and experimental food item using a mortar and pestle. After food samples were ground under distilled water, they were transferred into small test tubes using sterile disposable pipettes. All test tubes were placed in a water bath set at 100°C for 5 minutes and then centrifuged at maximum speed for 5 minutes. After students completed their DNA extractions, samples were placed in test tube racks and stored in a refrigerator until the next lab session.

Lab 7: Gymnosperms-The Naked Seed Plants

This lab included an introduction on gymnosperms, which are naked seed plants. Students in both labs viewed live Cycadophyta plants, a few microscope slides, and a large collection of herbarium and fresh specimens, representing ginkgo, gnetophytes, and conifers. Students were also able to view various examples of gymnosperms around WKU's campus, such as the ginkgo tree near the biology building.

Students in Group B used the first half of the lab session to cover material on gymnosperms. The second half of lab was used to complete part two of the experiments on genetically modified foods. A brief introduction on PCR was presented. Materials and step by step directions were provided for students to perform the experiment. DNA samples students previously prepared in part one of the experiment were removed from the refrigerator. PCR tubes were labeled and placed in capless microtube adaptors. Students added 20 µL of master mix and 20 µL of the indicated DNA sample to each PCR tube as shown in the experimental directions (Bio-Rad Laboratories, Inc. 2007). When instructed, students placed PCR tubes in the thermal cycler. PCR tubes were removed after all 40 cycles were completed; this is when the target DNA sequence of interest is sufficiently amplified (Bio-Rad Laboratories, Inc. 2007). Samples were refrigerated until the next lab session.

Lab 8: Angiosperms-Sexual Cycle: Flowers, Fruits, Seeds

The topic of angiosperms was introduced, which covers more derived plants and their flowering and fruiting features. Students in both labs received a thorough introduction on angiosperm plant characteristics and the processes of microsporogenesis and megasporogenesis. Students in Group A and Group B observed various plant specimens, plant models, and diverse fruit types, as well as dissected fresh flowers to study the morphology of flowers. In addition, a few slides were viewed under the microscope.

The experimental group completed part three of the experiments on genetically modified foods during the first half of lab. A brief description on gel electrophoresis and proper use of equipment was given before students began their experiment. Students were to visualize DNA fragments from the PCR products they amplified during part two of the experiment. Using pipettors, students added 10 μL of Orange G loading dye to each PCR tube containing the amplified DNA sample. Students set up their gel electrophoresis apparatus as instructed. Agarose gels used for electrophoresis were premade for student use. Students placed their agarose gel in the electrophoresis apparatus and added 0.25X TAE buffer until the gel was covered. Students loaded 20 μL of their samples in the appropriate wells and 20 μL of DNA standard in the last well of the gel. The gel electrophoresis apparatus for each group was connected to a power supply. Gels were run at 200V for 20 minutes. As the samples were running, students in Group B were introduced to the topic of angiosperms and viewed the lab material required.

When electrophoresis was complete, the power supply was turned off. Gels were carefully removed and placed into plastic containers, and immersed in 100X Fast Blast solution for 5 minutes. This quick staining dye was provided in the Bio-Rad GMO Investigator Kit. Gels were then rinsed with warm water three times to observe visible DNA bands. At the end of lab, after students in each group completed viewing material on angiosperms, they made observations of their gels and compared their sample DNA bands with the known DNA standard. Students were given a handout to analyze their results and made conclusions on whether their food sample was genetically modified or not.

Lab 9: Seed Germination: From Embryo to Adult Plant; Cells and Tissues of the Herbaceous Stem

The topic of seed germination was covered in this lab due to the considerable variation in plant structures amid angiosperms (Dillard 2004). Student in both labs studied the mature embryo sporophyte amongst angiosperms, viewed prepared slides of cells and tissues of herbaceous stems, labeled various figures in the lab manual, dissected a garden bean, and observed different stages of seedling development. They also were responsible for distinguishing unique characteristics of monocots and dicots when observing floral components, seed germination, and sections of stems. Students in Group B began a growth lab to observe seed germination in subsequent labs. Each student in Group B was provided sunflower and corn seeds, potting soil, and pots. After all seeds were planted, the containers were placed under a fluorescent light located in the back of the classroom. Students were responsible for watering their plants and observing plant growth during and after scheduled lab time. This created a hands-on approach for learning.

In addition, Group B conducted an experiment on seed germination using Wisconsin Fast Plants Kit™ (Carolina Biological Supply Co., Burlington, NC). Brassicaceae is a type of cruciferous plant, related to mustard, cabbage, and broccoli; they have been genetically modified to have a rapid life cycle (Williams 1986). These plants have a short development time of 14 days seed to flowering and grow well indoors under a fluorescent light source with little soil and water (Williams 1986). This activity provided an easy way to observe and carefully record the events of plant germination and development (Carolina Biological Supply Co. 2007).

Students in Group B received all materials and a handout with directions to carry out the experiments on seed germination. Students worked in pairs and set up two experiments using *Brassica rapa* seeds. During part one of the experiment, students in each group were provided a Petri dish, a transparency (plastic ruler disk), filter paper, a disposable pipette, and Wisconsin Fast Plant seeds (Carolina Biological Supply Co., Burlington, NC). Students placed the transparency disk face-up on the lid of the Petri dish. Then a round piece of filter paper was placed on top of the transparency. The filter paper was moistened by adding water with a disposable pipette. Each group added five seeds on the filter paper along the middle dark line of the ruler that is visible through the filter paper. Petri dishes were then placed in a large plastic container with shallow water under a fluorescent light source. Petri dishes were kept at a steep angle so that the bottom of the filter paper was below the water's surface; this served as the water source for the seeds. Students were provided individual data sheets to record the shoot and root length over a period of three weeks.

Part two of the experiment on seed germination was similar to part one; however seeds were grown in soil using quad cells provided in the Wisconsin Fast Plant Kit™ (Carolina Biological Supply Co., Burlington, NC). Students followed illustrated instructions provided in the kit (Carolina Biological Supply Co. 2007). Students in Group B planted their *Brassica rapa* seeds in the quad cells and placed them on a saturated mat with a reservoir of water. This allowed the soil to remain moist and plants to receive a continuous water supply. Students were directed to observe and record plant growth over a period of three weeks along with their Petri dishes they prepared in part one of the experiment. Students were responsible for watering their plants on a regular basis for this lab.

These two experiments allowed students to observe and compare seed germination and plant structural growth with and without soil as well as the importance of light and water for plant development. Growing seeds in Petri dishes gave students the opportunity to observe root growth, which they are unable to do when growing plants in soil.

Lab 10: Woody Stems

This lab required students to study woody plants and understand that secondary growth in plant tissues give rise to permanent structures (Dillard 2004). After a brief introduction, students in both labs observed a few prepared slides, external features of woody stems, wood blocks and labeled figures in their lab manuals.

After completing material for the lab, students in the experimental lab participated in an open inquiry learning activity. Students were put into groups and were given the freedom of designing a forensic botany case. Botanists have solved many cases by analyzing various plant structures as evidence related to a crime scene (Graham 2006). The advantage is that plant remains can be found almost everywhere and offer multiple sources of evidence, both macroscopic and microscopic, such as pieces of wood, seeds, fruits, leaves, twigs, pollen, and spores (Graham 2006). Each group was given the task of creating a crime scene scenario using woody plants, plant cells, and structures covered in lab as evidence. Students were also asked to briefly describe how the case is solved based on botanical evidence. A few articles providing examples and background information on forensic botany were handed out to each group. Students were also responsible for completing a scoring guide to evaluate all group members.

Lab 11: Leaves and Roots

This lab covered content on leaves and roots. Students observed prepared slides of plant cells, leaf anatomy, root anatomy, herbarium specimens showing morphological features of leaves, and types of roots. As students viewed this material, they labeled figures in their lab manuals.

In addition, Group B was introduced to the topic of medicinal botany. Many plants have long been used as medicinal components (Levetin et al. 2002). Leaves, stems, and roots of some plants are used for their medicinal properties. An experiment using fresh garlic extract at three different concentrations was performed on two types of bacterial cultures comprising *Bacillus subtilis* and *Escherichia coli* (Levetin et al. 2002). Filter paper disc agar diffusion method was used in measuring the antimicrobial effect garlic has against certain bacteria grown in culture (Levetin et al. 2002). Small filter paper discs were soaked in specific concentrations of garlic extract. Discs A were soaked in full-strength solution, discs B were soaked in 10% solution, discs C were soaked in 1% solution, and discs D were soaked in sterile deionized water and served as the negative control. Students made observations with the premade nutrient agar plates containing bacteria cultures. They were directed to measure the zone of inhibition that resulted from the diffusion of the garlic extract in the agar medium around the disc (Levetin et al. 2002). Students then completed a handout with their measurements and a set of questions analyzing the results.

Surveys

At the end of the semester, students in both labs received separate surveys to complete after their final exams. Survey questions and scales were designed after consulting three statisticians at WKU. The survey was worth 5 points of their written final exam score to encourage students to complete the surveys. Twenty students who received a survey thoroughly completed the entire packet of questions however, there were two students in Group A who did not complete the surveys and therefore were not included in the survey data. Surveys contained both quantitative and qualitative questions. Quantitative questions were designed on a scale of 1-7 based on how challenging, interesting, overwhelming, and intellectually stimulating (engaging) the labs were. Qualitative items presented students with an open response, which gave students the opportunity to express their ideas and opinions. The majority of the questions on both surveys were identical; however Group B received additional questions regarding lab activities, exercises, and experiments incorporated during the semester. All surveys were anonymous and did not affect students' grades. Students were directed to place the surveys in a box and sign in with office staff at WKU's Biology Department to receive points.

Statistical Package for the Social Sciences (SPSS)

All data collected from the surveys were entered into SPSS Version 14.0 for Windows. This program is used by many educational researchers for survey analysis. Statistical analysis included one-tailed, independent-samples t-test (due to the small group sizes) and comparison of means. A level of $p \leq 0.05$ was used to determine statistical significance.

RESULTS

The new experiments incorporated into Group B (experimental group) generated a lot of interest among students from the beginning of the semester. Since the same lab room was used for both lab sessions, students in Group A were curious about the experimental set ups in the classroom. Early in the semester, as students in Group A became aware of the differences in teaching methods and lab activities with Group B, many students in Group A wanted to change their schedules to join Group B taught on Thursdays. However, a cap was already placed on registration for the Thursday lab.

Both labs consisted of highly motivated and mature students. The college rank amongst students included one graduate student, a few sophomores, and majority juniors and seniors (Table 2). The grade distribution for both labs was similar, with most of the students earning a total percentage grade between 80% -100%. However, when comparing overall class averages, Group A received 86.0% and Group B received 90.7% (Fig. 3). Students in Group B definitely had a higher overall class average when compared to Group A. This suggests that learning levels were a little higher for students in Group B than Group A.

Students in Group B earned higher scores on majority of the assessments including lab assignments, quizzes, final exam, overall percentage, and extra credit (Fig. 3, Table 3). Group A scored slightly higher only for exam 1 compared to Group B.

Based on personal observations, students in Group B showed greater enthusiasm for this course throughout the semester when compared with Group A. On many occasions, students in Group A left class early after viewing the material for the lab. Students in Group B were willing to stay for the entire duration to finish experiments and review lab material. Students in Group B thoroughly completed all lab exercises, experiments, and handouts, in addition to the traditional lab material.

Survey questions were designed to collect student opinions. Quantitative and qualitative analyses were made using data from the surveys. Quantitative results for Group A and Group B were analyzed using SPSS. Independent samples t-test analyses were performed due to the small sample size. Few significant values were obtained due to the lack of statistical power resulting from low enrollment. However, a comparison between mean values was analyzed for Group A and Group B (Table 4, 5) to examine patterns noticed for each category from survey responses.

Mean values for each category across the 11 labs for the semester were compared between Group A and B (Fig. 4). Overall, when comparing responses for each category, students in Group A were slightly less challenged, interested, intellectually stimulated, and more overwhelmed when compared to students in Group B (Table 4). For the category of challenging, students in Group A had a mean value of 3.93, while students in Group B had a slightly higher mean value of 3.97 (p= .438). The category of interesting presents students in Group A having a lower mean value of 4.63 compared to Group B with a mean of 4.85 (p= .249). The next category of overwhelming shows students in Group A having a higher mean of 3.57 compared to Group B with a mean of 3.30 (p= .228). The last category of intellectually stimulating presents Group A with a lower mean value of 4.40 and Group B with a mean of 4.55 (p= .351). Significant values were not obtained due to the low sample number, therefore mean values were observed.

Each category was then separately analyzed (Figs. 5-8). The first set of bars on the graphs represents means across survey responses for the traditional material taught during both labs. The second set of bars on the graphs compares the means across the traditional material for Group A with the means across the traditional material plus experimental material for Group B. The last set of bars on the graphs represents the mean values for the experimental material alone (for Group B). Students in Group A did not receive survey questions on the experimental material since they did not pertain to their lab experience.

Students in Group B were more challenged when compared to Group A across all survey responses (Fig. 5). Group B perceived the new experiments to be slightly more challenging (Mean= 4.05) when compared to the traditional material (Mean= 3.97) (Fig. 5).

In the category of interest, students in Group B had a higher mean value for interest all across survey responses and had greater interest for the new experiments (Mean= 5.14) when compared to the traditional material (Mean=4.85) (Fig. 6).

In the category of overwhelming, students in Group A had higher mean values than Group B (Fig. 7). Interestingly, students in Group B were less overwhelmed with the new experiments (Mean= 3.11) when compared to the traditional labs (Mean= 3.30).

The last category compares how intellectually stimulating the lab exercises were for students. Those in Group B had higher means across all survey responses for intellectual stimulation (Fig. 8). Students in Group B felt that the new experiments were more intellectually stimulating (Mean= 5.01) than the traditional lab material (Mean= 4.55).

Additional responses were analyzed from the survey. Many responses were not included due to lack of significant values between means and t-values for the two labs.

However, a few significant values were noticed for a few questions. Table 6 represents a survey question all students received in regard to the 11 labs they conducted during the semester and the effects the labs had on their learning. The significant difference (p=.000) between student responses in Group A and Group B based on difficulty levels was noticed. Those in Group B had a higher mean (5.42) compared to students in Group A (Mean= 3.63).

A few significant values were also noticed among a set of questions in regard to specific labs and their interest for the course (Table 7). Significant values for the classification and microscope lab (p= .001), angiosperm lab (p= .008), and seed germination lab (p= .019) were evident. Students in Group A significantly showed more interest for the angiosperm and seed germination labs. Students in Group A also showed higher mean values for the woody plant identification lab (Lab 10) (Mean= 5.00) as well as the leaves and roots lab (Lab 11) (Mean= 4.38). These values were not significant, however students in Group A showed more interest. Students in Group B showed higher interest for the algae and cyanobacteria lab (Mean= 4.92) and woody stems lab (Mean= 4.58) which included case studies.

DISCUSSION

As a sophomore level course, students are gaining necessary skills for future biology courses or biology careers. Introducing students to experiments, case studies, and lab activities made the course more investigative. The strategies of inquiry, case-based, problem-based, and hands-on learning not only increased student learning, but interest level as well. An increase in student learning, interest, engagement, and retention levels were expected.

The updated lab manual incorporated color figures and images from the adopted textbook for the course (Fig. 2). This made learning easier for students when referring to figures in the textbook and identifying plants and their structures compared to the older edition (Fig. 1).

Using multiple teaching methods for lab activities allowed me to apply what best suited each lab rather than using just one method. All the methods implemented in various lab activities worked well and added excitement to the labs.

A similar project took place at Beijing Forestry University (BJFU), in which modifications were made to a botany course to make the content more interesting, informative, relevant and motivating by using more student-centered strategies built on the basis of traditional approaches (Zhonghua 2005). In this study, computer aided instructional (CAI) courseware was created for botany, students had full use of multimedia facilities, some creative experiments were applied, as well as a revised textbook and lab guide were used. The author recognized that any teaching strategy or method may not be appropriate for all students and teaching situations. "Strategies are often matched to objectives, so we must adopt different strategies according to teaching contexts by turn" (Zhonghua 2005). I used a comparable approach in the redesigning of experiments in this project. Some methods worked better than other. Following is a reflection on the methods used.

Analysis of inquiry learning methods incorporated

Structured inquiry can be a little restrictive in that students are provided everything to conduct the investigation. Structured inquiry worked well for the experiments on seed germination and medicinal plants. In retrospect, I might make these lab activities less structured by using guided inquiry learning methods, which gives students more freedom with investigation. This allows students to create their own testing conditions, rather than having a defined answer.

Students seemed to really benefit from the labs that integrated guided inquiry learning. Students had responsibility in completing the entire investigative activity and made their own conclusions. Students in Group B enjoyed the case study on water contamination during the algae and cyanobacteria lab (Table 7). These students were very involved in solving the case while viewing prepared slides and wet mounts of algae and cyanobacteria. The case study gave students a purpose to learn the material. Students in both labs also enjoyed the field trip at Lost River Cave to identify trees, however, students in Group B seemed to be more involved since a guided inquiry activity was implemented. This is represented by students in Group B having a higher mean of 5.00 compared to a mean value of 4.83 for Group A (Table 7). Students in Group B were highly motivated in properly identifying tree species since they had the incentive of plaques being placed on the trees they correctly identified. Students in Group B actively took pictures of the trees they identified with digital cameras provided for the lab. The pictures served the purpose of making sure students properly named the trees. Lastly, students in Group B appreciated the tour on invasive plant species. More students in Group B volunteered with the invasive plant removal project compared to students in Group A.

Open inquiry learning gave students the complete freedom of completing an investigative activity. The forensic botany case study was an example of this, in which students created and solved a forensic case using botanical knowledge. Students were given specific directions and guidelines, however not all groups met the expectations for this particular activity. A few students became more involved in creating a scene for the case rather then adding important botanical content as expected. Based on my experience, a guided inquiry learning method is preferred. The use of open inquiry is only beneficial when detailed descriptions, guidelines, and expectations are made clear to students upfront.

A study with open inquiry learning methods was performed by Lord et al. (2007) with a group of students taking college botany at Indiana University of Pennsylvania. This botany course was designed to give students complete freedom during the entire semester in deciding what botany content would be covered. Even though students had a lot of freedom, specific guidelines and expectations were explained in the beginning. Students received a list of precise lesson objectives and pertinent information to include in their presentations and discussions. "Peer-led discussions were usually thorough and provided a good review of the content. Occasionally, important issues were missed or were not dealt with at an appropriate depth." (Lord et al. 2007). At the beginning of each class, the instructor reviewed important content information as well as clarified or expanded information based on student presentations. "Most of the class members rated the course very highly and the majority said they would take another botany course if they could schedule it" (Lord et al. 2007). This study finds the use of open inquiry learning as a successful approach and could be a model for WKU with further work.

<u>Analysis of case-based learning</u>

As shown in Table 7, students in Group B had higher means for interest with the algae and cyanobacteria lab (Mean= 4.92) and woody stems lab (Mean= 4.58), which incorporated the use of cases. This method gave students a purpose in learning the material and applications to real-life situations without overwhelming students. This shows that students in Group B really enjoyed this teaching strategy.

Similarly, Zhonghua (2005) finds case studies to improve teaching and learning. This technique facilitates students by giving them an opportunity to redirect questions, make clarifications, as well highlight important points or issues.

<u>Analysis of problem-based learning</u>

This learning method allowed students to investigate botany related issues and apply them to real-life situations. Examples included genetically modified food products, phytoextraction and phytoremediation, and study of invasive plant removal. These topics allowed students to relate the botany lab material with current issues being researched as well as the benefits involved. These topics also introduced undergraduate students to various graduate research projects and plant science careers. Students in Group B exhibited more curiosity and interest when completing lab activities and observing traditional lab material compared to student in Group A.

According to Woods (1994), problem-based learning is an effective method in helping students develop skills such as critical thinking, self-directed and lifelong learning, problem solving, and teamwork abilities. Zhonghuar (2005) states that, “we come in contact with plants every day. Thus, many real problems can be used in a Botany course.” However, this study described the difficulty of using this design due to limited time available in class; using small solving projects during the course may be more successful (Zhonghuar 2005), which is the approach I used.

Analysis of hands-on learning

As a lab, the majority of learning occurs by hands-on methods. The additional hands-on learning opportunities engaged students when learning lab material. In particular, students in Group B significantly had more interest in the classification and microscope lab (p= .001) compared to students in Group A (Table 7). The thin-sectioning activity seemed to really improve the interest level amongst students.

The seed germination experiments and fern spore development activity were great hands-on experiences for the students, however they could have been a little more investigative. Also, spore development took too long to observe growth. Students were able to view growth during the end of the semester. Setting this lab activity earlier in the semester would be a solution for the long duration of growth.

The unexpectedly significant interest that Group A showed for the angiosperm (p= .008) and seed germination (p= .019) labs (Table 7) may be due to the fact that the traditional material in these labs contained many hands-on learning experiences in comparison to the rest of the labs covered by Group A. This implies that these two lab activities might have been the most exciting experiences during the semester for Group

A. Also, the greater interest that Group A showed for the woody plant identification lab and leaves and roots lab (Table 7) may possibly be due to the hands-on learning and macroscopic specimens used in these labs.

Surveys

The surveys allowed quantitative and qualitative measures to be analyzed. Student opinions were critical in analyzing how challenging, interesting, overwhelming, and intellectually stimulating each lab was. Due to small sample size there was a lack of statistical power and lack of significant values; instead mean values were compared. To increase student numbers, I considered incorporating other colleges and universities into the study however, this was too complicated and there was insufficient time to implement a larger study.

Overview of survey responses

Challenging

Overall, students in Group B were more challenged when learning lab material (Fig. 5). Challenge can be perceived as a positive or negative learning trait. In this case, I would characterize challenge as a positive learning aspect since students in Group B portrayed high interest levels, high intellectual stimulation, and were not as overwhelmed with the lab material.

Interesting

The additional experiments and new teaching strategies improved overall interest among botany students in Group B. Based on observations, students in Group B were more curious, interactive, and engaged during the semester compared to students in Group A. Fig. 6 also illustrates student survey responses on interest levels. Students in

Group B reacted overall with higher interest for both traditional material and new material compared to those in Group A. Students in Group B presented the highest interest for the new material incorporated. Based on observation, as students in Group B were introduced to new topics incorporated in the lab manual, they showed greater interest in learning lab material.

Overwhelming and Difficulty

Interestingly, for the category of students feeling overwhelmed with lab material, students in Group A felt more overwhelmed than students in Group B (Fig. 7). The experiments and lab exercises might have made learning more enjoyable with more investigative and hands-on learning; students were able to make connections and the material did not appear to be monotonous. The higher means for Group B in Table 6 suggest that students in Group B had less difficulty learning lab material in contrast with students in Group A having more difficulty. A representative student from Group A stated that the labs conducted during the semester "made learning more boring. It was like every other typical lab and was monotonous in how it worked." A representative student in Group B stated, "The labs helped to fully understand and get more experience with what we were studying." Overall, students in Group B felt that the labs conducted during the semester made learning botany content easier.

Intellectually Stimulating

Students in Group B were more intellectually stimulated for both traditional material and new material compared to those in Group A (Fig. 8). This is correlated with student interest levels. The overall lab experience appeared to be more interesting and engaging for students in Group B. Many students in Group B stated that they really enjoyed the real-life applications and hands-on work with the botany material.

Student Performance

As shown in Figure 3 and Table 3, students in Group B had higher means across the grade distribution, except for the midterm exam. Students in Group B did exceptionally well on the final exam and overall percentage for the course. The higher mean values for Group B (Table 3) indicates that students benefitted from higher learning retention based on their assessment results. Incorporating the various new lab exercises was beneficial for student learning.

Recommendations

In the future, more time could be spent in designing and improving cases as well as having students spend more time growing plants. The only labs I would make changes to would be with the woody stems activity by not using open inquiry, as well as the experiment conducted with fern spores since spore germination took a longer time to develop than expected. I would begin this exercise earlier in the semester.

Overall, I was able to add excitement to these labs without compromising any of the original content. The biggest issue with converting labs to an investigative format is the concern that excessive time will be required to complete inquiry labs, to the point that at least some of the original material will have to be omitted. However, the amount of information being added to create the redesigned labs was not overwhelming and was worth the added benefits for the students.

Future Directions

Student enrollment in Plant Biology and Diversity as well as upper level plant science courses will likely increase at WKU. When sufficient changes to the labs result in higher enrollment, it might allow researchers to study more significant statistical analyses. In addition, performance on future senior assessment exams will be evaluated. It is expected that these changes will result in WKU students performing closer to national averages. After the revisions have been piloted at WKU, other universities could also be solicited to incorporate these changes and conduct further study.

Table 1: WKU Plant Biology and Diversity Lab Enrollment
For Academic Years 2001-2007

Academic year	Number of students enrolled in BIOL 223
Fall 2001	41
Spring 2002	52
Fall 2002	55
Spring 2003	49
Fall 2003	58
Spring 2004	48
Fall 2004	50
Spring 2005	45
Fall 2005	45
Spring 2006	24
Fall 2006	11
Fall 2007	22

Table 2: Student Grade Point Averages

	Student	Gender	College Rank	Biology GPA	Cumulative GPA
Group A	A	Male	Graduate	3.83	3.80
	B	Female	Junior	3.26	3.75
	C	Female	Sophomore	1.92	2.26
	D	Male	Senior	3.20	2.74
	E	Female	Junior	4.00	3.92
	F	Male	Junior	3.97	3.50
	G	Female	Non-Traditional/ Junior	4.00	2.78
	H	Female	Senior	3.88	3.22
	I	Female	Senior	3.56	3.51
	J	Male	Sophomore	2.67	2.01
Group B	K	Female	Junior	3.24	3.43
	L	Male	Senior	4.00	4.00
	M	Male	Sophomore	3.79	3.87
	N	Male	Sophomore	3.06	3.64
	O	Male	Junior	3.49	3.55
	P	Female	Junior	2.69	2.76
	Q	Male	Junior	2.23	3.26
	R	Male	Sophomore	2.76	3.23
	S	Female	Senior	2.26	2.73
	T	Female	Junior	2.82	3.04
	U	Female	Senior	4.00	3.94
	V	Female	Senior	3.26	3.50

Note: GPA's are based on a 4.0 Scale

Table 3: Means for Score Distribution

	Group A	Group B
11 Lab Assignments (10 pts. each)	9.44	9.95
10 Quizzes (10pts. each)	8.04	8.63
Midterm Exam (100 pts.)	84.70	84.29
Final Exam (100 pts.)	77.90	86.75
Overall Percentage (100%)	86	90.67
Extra Credit (10pts.)	5.00	5.83

Table 4: Means and independent samples t-tests across 11 labs for Group A and Group B

Question Type	Group A N=8 Mean	Group B N=12 Mean	t	p (one-tailed)
challenging	3.93 ±.53	3.97 ±.52	-.158	.438
interesting	4.63 ±.80	4.85 ±.55	-.743	.249
overwhelming	3.57 ±.83	3.30 ±.76	.762	.228
intellectually stimulating	4.40 ±1.13	4.55 ±.67	-.388	.351

Note: No significant values

Table 5: Means and independent samples t-test across traditional material for Group A and traditional & new material for Group B

Question Type	Group A N=8 Mean	Group B N=12 Mean	t	p (one-tailed)
challenging	3.93 ±.53	4.00 ±.61	-.274	.394
interesting	4.63 ±.80	4.97 ±.70	-1.016	.162
overwhelming	3.57 ±.83	3.22 ±.73	.994	.167
intellectually stimulating	4.40 ±1.13	4.75 ±.79	-.812	.214

Note: No significant values

Table 6: Selected survey question
Survey Question-The labs we conducted in this course had the following effect on my learning:

Group A		Group B			
Mean	N	Mean	N	t	p (one-tailed)
3.63 ±.74	8	5.42 ±.90	12	-4.66	.000*

Note: * $p \leq .05$
On a scale of 1-7, 1 made learning harder, 7 made learning easier. Students in Group B (the experimental group) had a higher mean compared to Group A.

Table 7: Survey responses for selected lab activities.
Survey Question- What impact did each of the following labs have on you interest for this course?

Lab Activity	Group A N= 8 Mean	Group B N= 12 Mean	Sig. (one-tailed)
Classification & Microscope	1.75 ±.89	3.92 ±1.56	.001*
Woody Plant Identification	5.00 ±2.33	4.83 ±1.47	.422
Algae & Cyanobacteria	4.00 ±1.41	4.92 ±1.24	.072
Angiosperms	5.88 ±1.25	4.42 ±1.17	.008*
Seed Germination	5.63 ±1.60	4.33 ±.99	.019*
Woody Stems	4.50 ±1.93	4.58 ±1.08	.452
Leaves and Roots	4.38 ±1.92	4.25 ±.97	.425

Note: * $p \leq .05$
Responses were on a scale of 1-7, 1 having the lowest impact and 7 having the highest impact.

PARENCHYMA

Parenchyma are the least specialized of plant cells and occur in all plant organs. You should note that they have a relatively thin primary cell wall only. Parenchyma cells function primarily in food and water storage and photosynthesis. ***STUDY THE PREPARED SLIDE*** of a cross-section of the leaf of a vascular plant (probably *Ligustrum sp.*, "privet;" (**Text Fig. 26-20 a, b**). Note, just beneath the **upper epidermis**, some closely "packed" (*i.e.*, with virtually no intercellular spaces) columnar parenchyma cells which contain numerous chloroplasts. This layer of parenchymatous photosynthetic cells is referred to as the **palisade parenchyma**. Between the palisade parenchyma layer(s) and the **lower epidermis** appear several layers of loosely "packed" (*i.e.*, with large intercellular spaces) spherical parenchyma cells which have relatively few chloroplasts. This area of parenchyma is referred to as the **spongy parenchyma**. Make a sketch as you deem necessary.

STUDY THE PREPARED SLIDE of a cross-section of a young root (probably *Ranunculus sp.*, "buttercup;" **Text Fig. 25-10**). Note the **epidermis**. Note also the extensive region <u>between</u> the **epidermis** and the **endodermis** which is occupied by rather large **parenchyma** cells; this region is called the **cortex**. Note that the cortical parenchyma cells contain numerous purple-stained **starch grains**, the reserve food. The **endodermis** is easily recognized; it is a single layer of cells some of which have distinctive red-stained cell walls due to the presence of suberin deposited in strips (= Casparian strips). That portion of the root internal to the **endodermis** is referred to as the vascular cylinder (= stele), containing the **xylem** and the **phloem**. Label the following figure: **epidermis; cortex (parenchyma); endodermis; xylem; phloem; stele.**

Cross-Section of *Ranunculus sp.* Root

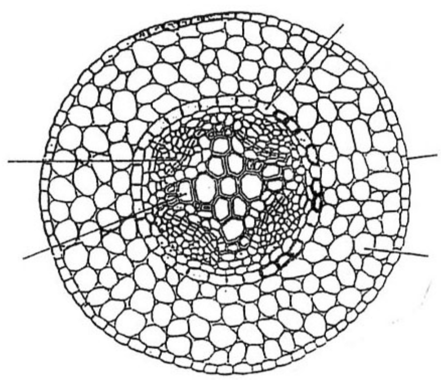
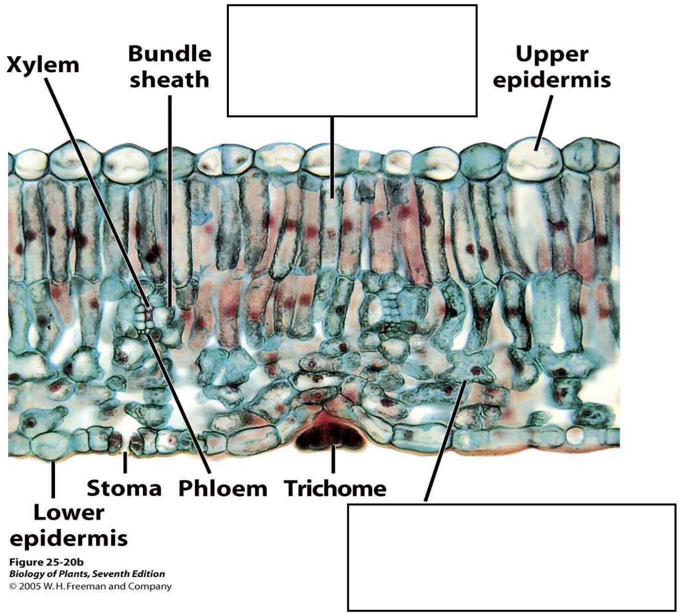
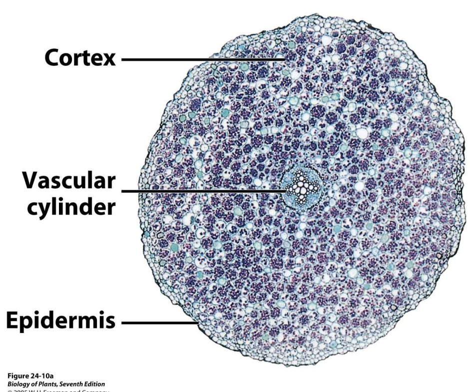


Figure 1. Example page from older edition botany lab manual used by Group A.

Label palisade parenchyma and spongy parenchyma in the correct boxes in the figure shown below.



Study the prepared slide of a cross-section of a young root (probably *Ranunculus*, butter-cup) (**Text Fig. 24-10**). Note the extensive region between the epidermis and the endodermis occupied by parenchyma cells; this region is called the **cortex**. Note that the cortical parenchyma cells contain numerous starch grains.



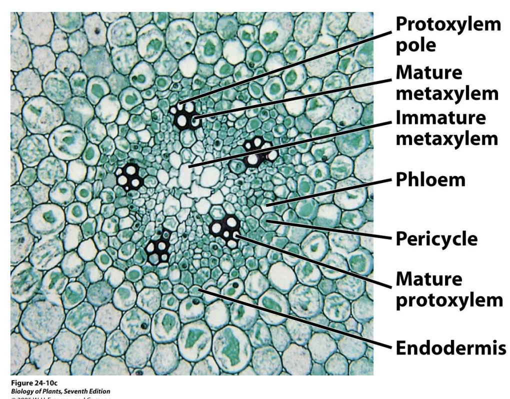


Figure 2. Example page from updated botany lab manual used by Group B.

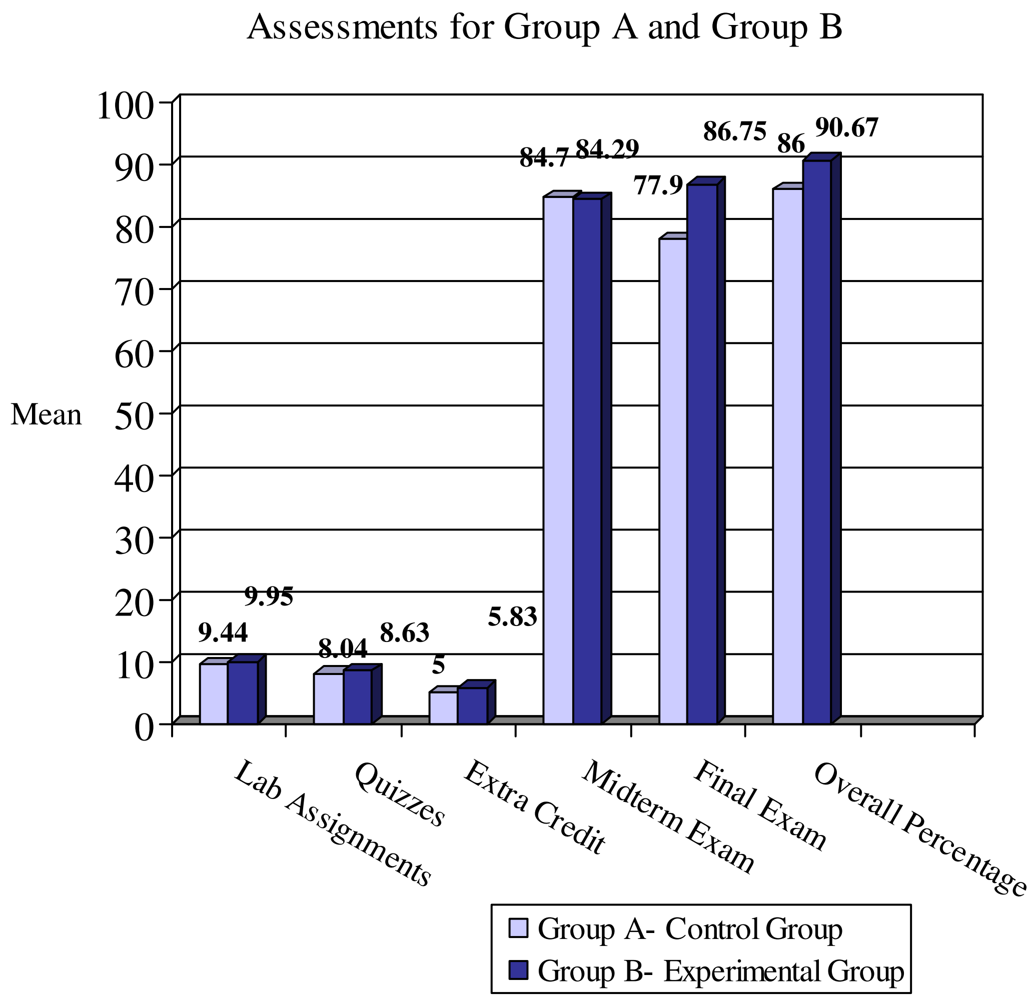


Figure 3. Students in Group A and Group B received the same traditional objective quizzes, exams, and written lab assignments during the semester. Graph represents mean values of assessments, which included 11 lab assignments (each worth 10 points), ten quizzes (each worth 10 points), midterm and final exam (each worth 100 points- 75 points practical exam and 25 points written exam), and a community service extra credit opportunity on invasive plant removal at Lost River Cave, Bowling Green, KY. Overall percentage includes mean values for students' total percentage for Group A and Group B.

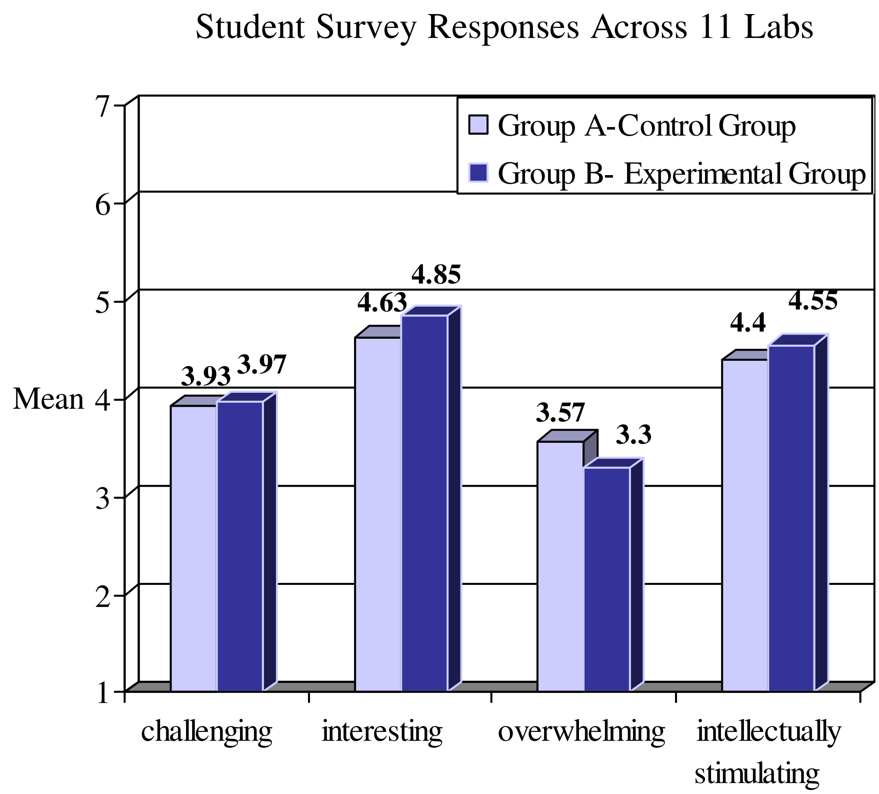


Figure 4. Survey responses for 11 labs on how challenging, interesting, overwhelming, and intellectually stimulating each lab was for students in Group A and Group B. Overall mean values for Labs 1-11 are represented.

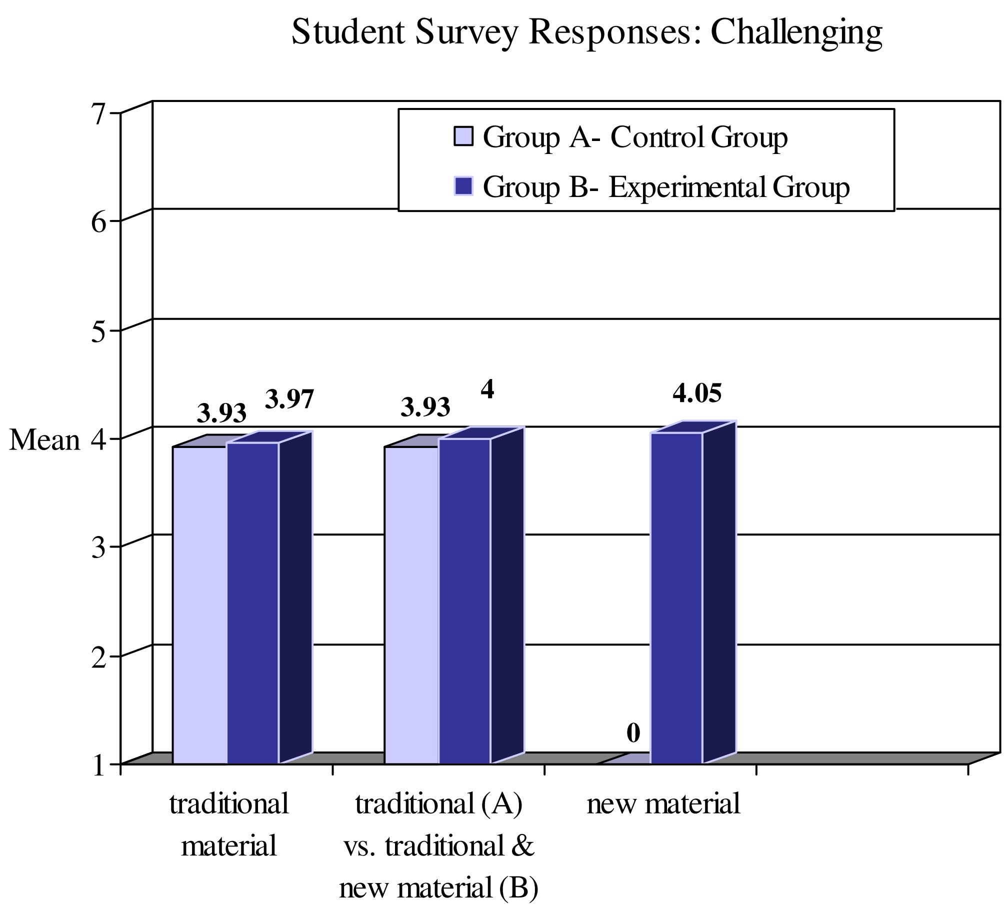


Figure 5. Category of survey questions on challenge of labs. The first set of bars represents means across survey responses for the traditional material taught during both labs. The second set of bars compares means across the traditional material for Group A with the mean across the traditional material plus new experimental material for Group B. The last set of bars represents the mean values for the experimental material alone for Group B. Students in Group A did not receive survey questions on new material since these questions did not pertain to their lab experience.

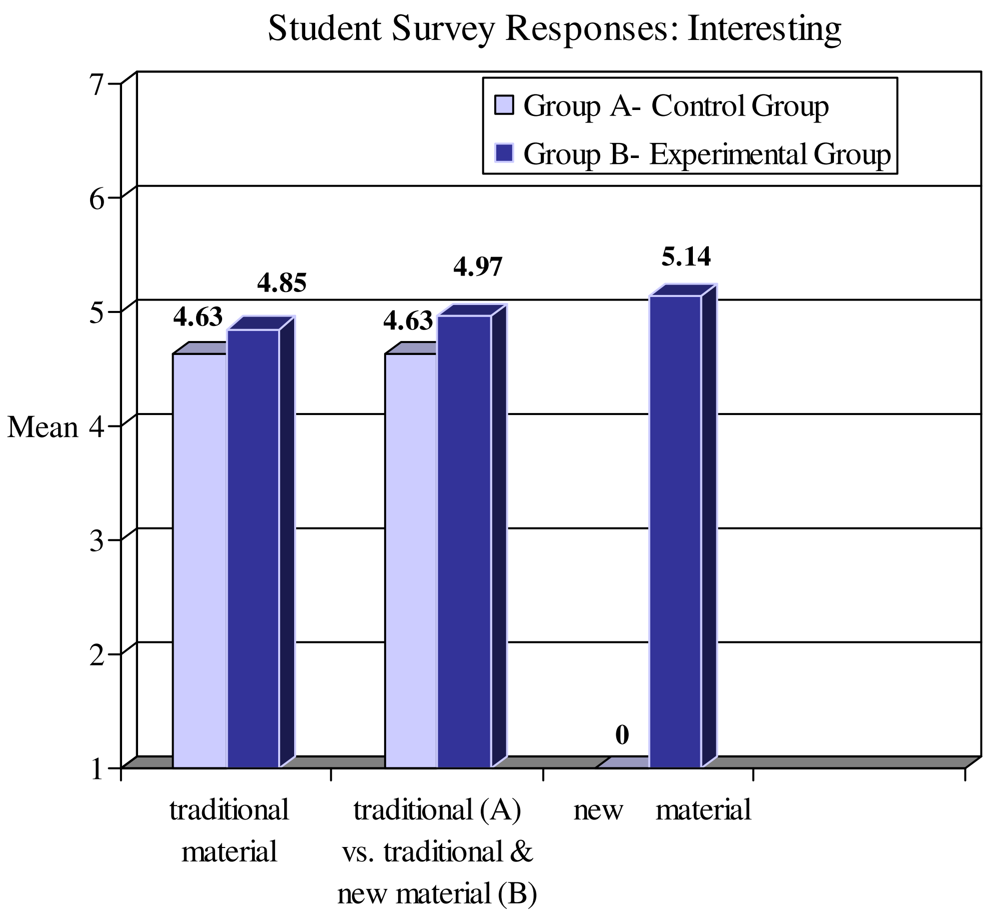


Figure 6. Category of survey questions on interest on labs. The first set of bars represents means across survey responses for the traditional material taught during both labs. The second set of bars compares means across the traditional material for Group A with the mean across the traditional material plus new experimental material for Group B. The last set of bars represents the mean values for the experimental material alone for Group B. Students in Group A did not receive survey questions on new material since these questions did not pertain to their lab experience.

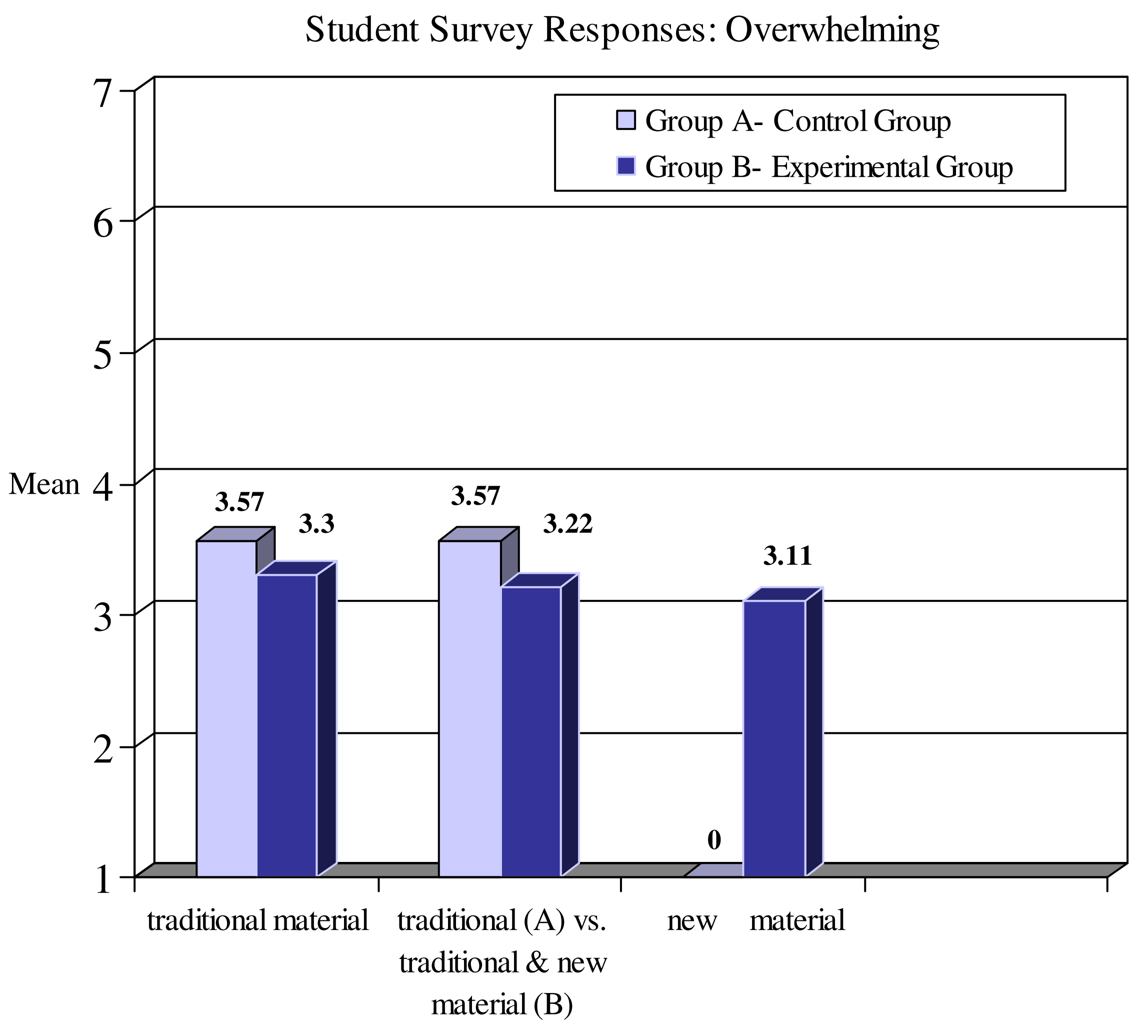


Figure 7. Category of survey questions on how overwhelming each lab seemed. The first set of bars represents means across survey responses for the traditional material taught during both labs. The second set of bars compares means across the traditional material for Group A with the mean across the traditional material plus new experimental material for Group B. The last set of bars represents the mean values for the experimental material alone for Group B. Students in Group A did not receive survey questions on new material since these questions did not pertain to their lab experience.

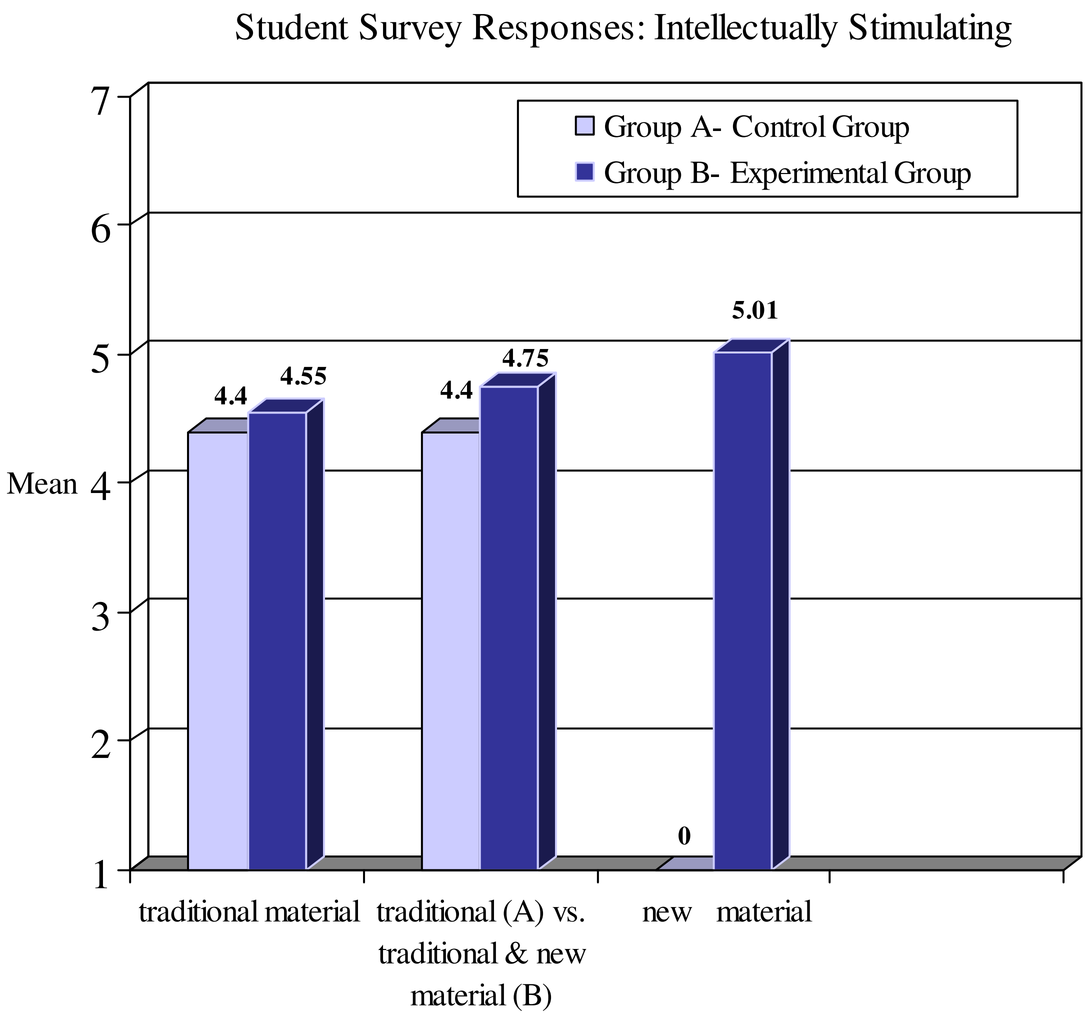


Figure 8. Category of survey questions on intellectual stimulation of labs. The first set of bars represents means across survey responses for the traditional material taught during both labs. The second set of bars compares means across the traditional material for Group A with the mean across the traditional material plus new experimental material for Group B. The last set of bars represents the mean values for the experimental material alone for Group B. Students in Group A did not receive survey questions on new material since these questions did not pertain to their lab experience.

APPENDIX

Survey Questions for Group A

1) Place a check next to any of the following college ranks that apply to you.
___freshman ___sophomore ___junior ___senior ___graduate

___honors student ___non-traditional student

2) What grade are you expecting in this course? Circle one. A B C D F

Directions:
On a scale of 1 to 7; 1 being the lowest and 7 being the highest, circle your responses below.

3) Lab 1: Introduction to Classification and the Microscope.
This lab included a classification activity and learning the basic parts of a microscope.

How challenging was Lab 1?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 1?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 1?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 1?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

4) Lab2: Tree Identification
The use of a dichotomous key was used along with becoming familiar with specific leaf morphology. Trees were identified at Lost River Cave along with the community service project.

How challenging was Lab 2?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 2?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 2?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 2?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

5) Lab 3: Algal Groups
Various algae specimens were studied in lab, which included prepared slides and live samples.

How challenging was Lab 3?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 3?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 3?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 3?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

6) Lab 4: Introduction to Plant Cells and Tissues
Various prepared slides were observed in becoming familiar with plant anatomical structures

How challenging was Lab 4?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 4?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 4?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 4?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

7) Lab 5: Bryophytes
Various prepared slides and preserved specimens of the bryophyte phyla were observed along with their anatomical structures.

How challenging was Lab 5?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 5?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 5?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 5?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

8) Lab 6: Cryptogams (Non-Seed Producing Vascular Plants)
Various prepared slides, herbarium, and live specimens of Cryptogams were observed along with their anatomical structures.

How challenging was Lab 6?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 6?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 6?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 6?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

9) Lab 7: Gymnosperms (Cone-Bearing Seed Plants)
Various prepared slides, herbarium, and live specimens of Gymnosperms were observed along with their anatomical structures.

How challenging was Lab 7?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 7?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 7?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 7?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

10) Lab 8: Angiosperms
Various prepared slides, models, and live specimens of Angiosperms were observed along with their anatomical structures. Flower dissections were done on a monocot and dicot flower. Also various fruit types were categorized by observing fresh and dried fruit samples

How challenging was Lab 8?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 8?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 8?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 8?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

11) Lab 9: Seed Germination
Prepared slides of plant tissues and cells were observed. In addition, a dissection of a garden bean and observation of a 7 day seedling were done. You were also able to plant your own sunflower seeds and watch them germinate.

How challenging was Lab 9?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 9?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 9?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 9?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

12) Lab 10: Woody Stems
A few prepared slides and woody samples were studied during this lab.

How challenging was Lab 10?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 10?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 10?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 10?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

13) Lab 11: Leaves and Roots
Prepared slides and herbarium specimens were observed to study leaf and root morphology and anatomy.

How challenging was Lab 11?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 11?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 11?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 11?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

14) Do you feel that the incorporation of additional experiments, exercises, and case studies would have helped you learn the lab material better for this course? Write your response in the box below.

For example: When studying Angiosperms, an additional experiment on Genetically Modified Organisms would be conducted. Various techniques such as DNA extraction of various foods products w, Polymerase Chain Reaction (PCR), and Gel Electrophoresis to study DNA bands would be incorporated.

15) Do you think that additional experiments, exercises, and case studies (investigative/ problem based learning methods) would enhance your overall learning experience for this course? Circle your response below.

Investigative cases draw from realistic situations in which scientific reasoning can be applied.

Problem-based learning is experiential learning (hands-on learning) around the investigation and resolution of real life situations.

No enhancement learning	1	2	3	4	5	6	7	Great enhancement to learning

16) The traditional learning methods used for the labs in this course had the following effect on my learning. (Traditional learning included a brief lecture, observation of prepared slides, herbarium specimens, live specimens, and a few plant dissections.)

a)

Made learning harder	1	2	3	4	5	6	7	Made learning easier

b) Please describe why you think this:

On a scale of 1-7; 1 being the lowest and 7 being the highest, circle your responses below. (Refer to #'s 3-13 for lab descriptions.)

17) What impact did each of the following labs have on your interest for this course? On a scale of 1-7; 1 being the lowest and 7 being the highest, circle your responses below.

Lowest Impact								Highest Impact
Classification & Microscope Introduction	1	2	3	4	5	6	7	
Tree Identification	1	2	3	4	5	6	7	
Algal Groups	1	2	3	4	5	6	7	
Intro. to Plant Cells & Tissues	1	2	3	4	5	6	7	
Bryophytes	1	2	3	4	5	6	7	
Cryptogams (Non-Seed Producing Vascular Plants)	1	2	3	4	5	6	7	
Gymnosperms (Seed-Producing Vascular Plants)	1	2	3	4	5	6	7	
Angiosperms	1	2	3	4	5	6	7	
Seed Germination	1	2	3	4	5	6	7	
Woody Stems	1	2	3	4	5	6	7	
Leaves and Roots	1	2	3	4	5	6	7	

18) How comfortable were you with the level of required work for this course?

Not comfortable	1	2	3	4	5	6	7	Very comfortable

19) Which method would you find more helpful in studying lab material for this course?

Labeling your own drawings	1	2	3	4	5	6	7	Labeling pre-drawn drawings
Labeling black & white figures	1	2	3	4	5	6	7	Labeling color figures

20) Describe what you liked <u>most</u> about this course?

21) Describe what you liked <u>least</u> about this course?

22) Do you suggest further changes for this course? Describe.

23)
Please circle the number that indicates your current <u>interest</u> level in the areas below:

Interest in…	Low Interest						High Interest
Investigative/Problem Based learning *	1	2	3	4	5	6	7
Being able to understand advanced topics : plant science	1	2	3	4	5	6	7
Case studies	1	2	3	4	5	6	7
Using hands-on methods	1	2	3	4	5	6	7
Working in group to complete class assignments	1	2	3	4	5	6	7
Pursuing a career in plant science	1	2	3	4	5	6	7

* Investigative cases draw from realistic situations in which scientific reasoning can be applied.

* Problem-based learning is experiential learning (hands-on learning) around the investigation and resolution of real life situations.

24) Do you feel that you had an opportunity to work in groups in this lab?

_____yes _____no _____sometimes

If so, did this help you learn lab material significantly?

25) Compared to other courses you have taken at WKU, <u>how interesting</u> was this course?

Least interesting	1	2	3	4	5	6	7	Most interesting

26) I think that the concepts I learned from this course will be useful to me later on.

Disagree	1	2	3	4	5	6	7	Agree

27) The instructor did a good job of helping us to understand lab material for this course.

Disagree	1	2	3	4	5	6	7	Agree

28) Overall, this course met my expectations.

Expectations were not met	1	2	3	4	5	6	7	Expectations were met

29) Would you suggest this course to another student? Why?

Survey Questions for Group B

1) Place a check next to any of the following college ranks that apply to you.
___freshman ___sophomore ___junior ___senior ___graduate

___honors student ___non-traditional student

2) What grade are you expecting in this course? Circle one. A B C D F

Directions:
On a scale of 1 to 7; 1 being the lowest and 7 being the highest, circle your responses below.

3) Lab 1: Introduction to Classification and the Microscope.
This lab included a classification activity and learning the basic parts of a microscope.

How challenging was Lab 1?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 1?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 1?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 1?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

4) Lab2: Tree Identification
The use of a dichotomous key was used along with becoming familiar with specific leaf morphology. Trees were identified at Lost River Cave along with the community service project.

How challenging was Lab 2?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 2?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 2?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 2?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

5) Lab 3: Algal Groups
Various algae specimens were studied in lab, which included prepared slides and live samples.

How challenging was Lab 3?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 3?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 3?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 3?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

6) Lab 4: Introduction to Plant Cells and Tissues
Various prepared slides were observed in becoming familiar with plant anatomical structures

How challenging was Lab 4?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 4?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 4?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 4?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

7) Lab 5: Bryophytes
Various prepared slides and preserved specimens of the bryophyte phyla were observed along with their anatomical structures.

How challenging was Lab 5?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 5?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 5?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 5?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

8) Lab 6: Cryptogams (Non-Seed Producing Vascular Plants)
Various prepared slides, herbarium, and live specimens of Cryptogams were observed along with their anatomical structures.

How challenging was Lab 6?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 6?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 6?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 6?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

9) Lab 7: Gymnosperms (Cone-Bearing Seed Plants)
Various prepared slides, herbarium, and live specimens of Gymnosperms were observed along with their anatomical structures.

How challenging was Lab 7?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 7?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 7?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 7?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

10) Lab 8: Angiosperms
Various prepared slides, models, and live specimens of Angiosperms were observed along with their anatomical structures. Flower dissections were done on a monocot and dicot flower. Also various fruit types were categorized by observing fresh and dried fruit samples

How challenging was Lab 8?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 8?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 8?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 8?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

11) Lab 9: Seed Germination
Prepared slides of plant tissues and cells were observed. In addition, a dissection of a garden bean and observation of a 7 day seedling were done. You were also able to plant your own sunflower seeds and watch them germinate.

How challenging was Lab 9?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 9?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 9?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 9?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

12) Lab 10: Woody Stems
A few prepared slides and woody samples were studied during this lab.

How challenging was Lab 10?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 10?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 10?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 10?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

13) Lab 11: Leaves and Roots
Prepared slides and herbarium specimens were observed to study leaf and root morphology and anatomy.

How challenging was Lab 11?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for Lab 11?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in Lab 11?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was Lab 11?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

Directions:
On a scale of 1 to 7; 1 being the lowest and 7 being the highest, cAdditional exercises, experiments, and case studies were incorporated in many of the labs. Circle your responses below based on your opinion of the additional material.

14) Cross-section of stems:
Cross-sections of a monocot stem were made using a fresh plant sample and razor blade. The cross-sections were observed under the microscope.

How challenging was this experiment?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for this experiment?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in this experiment?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was this experiment?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

15) Tree Identification:
Basic leaf morphology was introduced along with using a dichotomous key for tree identification. Tree identification was done at Lost River Cave along with the community service project. Topic of invasive species was introduced.

How challenging was this experiment?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for this experiment?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in this experiment?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was this experiment?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

16) Algae Water Contamination Case Study:
You were given a case study on the death of cattle on a farm, possibly due to contaminated pond water. Your task was to confirm and identify the algae causing this problem as you analyzed the live samples and prepared slides in lab.

How challenging was this experiment?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for this experiment?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in this experiment?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was this experiment?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

17) Spore Proliferation:
After studying the Cryptogams, a brief experiment was started by poring diluted samples of fern spores on fern nutrient agar plates. The plates were put under a light source for a period of 5 weeks to see if fern prothalial growth can be observed.
How challenging was this experiment?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for this experiment?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in this experiment?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was this experiment?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

18) Wisconsin Fast Plants/Seed Germination:
Each group was given a Petri dish and a 4-chambered container with soil to study seed germination. These seeds are designed to observed rapid growth in order to study the process of seed germination. Observations and data were collected gradually. You were also able to plant your own sunflower seeds to observe the process of seed germination.
How challenging was this experiment?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for this experiment?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in this experiment?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was this experiment?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

19) Genetically Modified Foods:
Topic of genetically modified organisms was introduced. A 3 week experiment was conducted. The first week DNA samples were taken from various food samples. The second week PCR (Polymerase Chain Reaction) was conducted. The third week, Gel Electrophoresis was done to analyze DNA bands of your samples.

How challenging was this experiment?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for this experiment?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in this experiment?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was this experiment?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

20) Forensic Botany:
Each group was given the task of creating a Crime Scene Investigation Case using plant structures as evidence.

How challenging was this experiment?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for this experiment?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in this experiment?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was this experiment?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

21) Medicinal Botany/Bacterial Cultures:
Topic of medicinal botany was introduced. An experiment on antibacterial properties of garlic was analyzed by observing zones of inhibitions of bacteria cultures with various dilutions of garlic.

How challenging was this experiment?

Least Challenging	1	2	3	4	5	6	7	Most Challenging

How interesting was the material for this experiment?

Least Interesting	1	2	3	4	5	6	7	Most Interesting

How overwhelming was the material covered in this experiment?

Least Overwhelming	1	2	3	4	5	6	7	Most Overwhelming

How intellectually stimulating was this experiment?

Not Stimulating	1	2	3	4	5	6	7	Very Stimulating

22) Do you feel that the additional experiments described above helped you learn better?

23) Did you find the additional experiments beneficial in retaining information for lab material? Explain.

24) Do you think the additional experiments, exercises, and case studies enhanced your overall learning experience? Circle your response below.

No enhancement to learning	1	2	3	4	5	6	7	Great enhancement to learning

25) The experiments we conducted in this course had the following effect on my learning:

a)

Made learning harder	1	2	3	4	5	6	7	Made learning easier

b) Please describe why you think this:

26 What impact did each of the following labs have on your interest for this course? On a scale of 1-7; 1 being the lowest and 7 being the highest, circle your responses below.

Lowest Impact								Highest Impact
Classification & Microscope Introduction	1	2	3	4	5	6	7	
Tree Identification	1	2	3	4	5	6	7	
Algal Groups	1	2	3	4	5	6	7	
Intro. to Plant Cells & Tissues	1	2	3	4	5	6	7	
Bryophytes	1	2	3	4	5	6	7	
Cryptogams (Non-Seed Producing Vascular Plants)	1	2	3	4	5	6	7	
Gymnosperms (Seed-Producing Vascular Plants)	1	2	3	4	5	6	7	
Angiosperms	1	2	3	4	5	6	7	
Seed Germination	1	2	3	4	5	6	7	
Woody Stems	1	2	3	4	5	6	7	
Leaves and Roots	1	2	3	4	5	6	7	

27) How comfortable were you with the level of required work for this course?

Not comfortable	1	2	3	4	5	6	7	Very comfortable

28) Which method would you find more helpful in studying lab material for this course?

Labeling your own drawings	1	2	3	4	5	6	7	Labeling pre-drawn drawings
Labeling black & white figures	1	2	3	4	5	6	7	Labeling color figures

29) Describe what you liked <u>most</u> about this course?

30) Describe what you liked <u>least</u> about this course?

31) Do you suggest further changes for this course? Describe.

32)
Please circle the number that indicates your current interest level in the areas below:

Interest in…	Low Interest						High Interest
Investigative/Problem Based learning *	1	2	3	4	5	6	7
Being able to understand advanced topics in plant science	1	2	3	4	5	6	7
Case studies	1	2	3	4	5	6	7
Using hands-on methods	1	2	3	4	5	6	7
Working in group to complete class assignments	1	2	3	4	5	6	7
Pursuing a career in plant science	1	2	3	4	5	6	7

* Investigative cases draw from realistic situations in which scientific reasoning can be applied.

* Problem-based learning is experiential learning (hands-on learning) around the investigation and resolution of real life situations.

33) Do you feel that you had an opportunity to work in groups in this lab?

____yes ____no ____sometimes

If so, did this help you learn lab material significantly?

34) Compared to other courses you have taken at WKU, how interesting was this course?

Least interesting	1	2	3	4	5	6	7	Most interesting

35) I think that the concepts I learned from this course will be useful to me later on.

Disagree	1	2	3	4	5	6	7	Agree

36) The instructor did a good job of helping us to understand lab material for this course.

Disagree	1	2	3	4	5	6	7	Agree

37) Overall, this course met my expectations.

Expectations were not met	1	2	3	4	5	6	7	Expectations were met

38) Would you suggest this course to another student? Why?

Phytoextraction and Phytoremediation Questions:

Answer the following questions using various sources, such as the journal articles provided, your textbook, internet, library, etc. Provide a list of your reference(s) at the end.

1. Define phytoextraction and phytoremediation.

2. List 3 purposes for phytoextraction.and phytoremediation.

3. Explain how these processes constitute a form of "Green Technology," meaning that it is environmentally friendly.

4. List 2 plants commonly used in these processes or can any type of plant be used.

Survey Data

			Lab 1: Microscope				Lab 2: Tree Identification			
Group A	Q1	Q2	Q3a	Q3b	Q3c	Q3d	Q4a	Q4b	Q4c	Q4d
Student			Challenging	Interesting	Overwhelming	Stimulating	Challenging	Interesting	Overwhelming	Stimulating
1	Junior/HS	A	3	2	4	2	3	4	5	4
2	Senior	A	1	1	1	2	5	4	4	5
3	Senior	B	1	2	2	2	4	6	2	4
4	Junior/HS	A	1	2	1	1	4	5	2	5
5	Junior	A	1	3	1	1	4	6	4	5
6	Junior/NT	B	6	1	6	4	5	3	4	2
7	Senior/HS	A	1	4	1	4	2	7	1	5
8	Senior	A	3	5	3	5	5	7	5	7
Average			2.125	2.5	2.375	2.625	4	5.25	3.375	4.625
Group B	Q1	Q2	Q3a	Q3b	Q3c	Q3d	Q4a	Q4b	Q4c	Q4d
9	Sophomore/HS	A	1	3	2	2	4	3	3	4
10	Sophomore	A	2	2	2	2	4	3	3	4
11	Senior	A	1	3	1	2	4	6	3	4
12	Senior	B	4	4	2	3	4	4	2	3
13	Senior/HS	A	2	2	1	2	5	3	2	3
14	Junior	B	3	4	2	5	4	4	2	5
15	Senior	A	1	4	1	3	2	5	2	5
16	Sophomore	A	1	3	1	3	5	5	3	5
17	Junior/HS	A	2	4	1	4	3	5	2	4
18	Junior	A	2	3	2	2	4	6	3	5
19	Junior/HS	B	4	4	2	3	4	6	3	6
20	Junior	B	2	4	1	4	4	5	3	3
Average			2.08	3.33	1.50	2.92	3.92	4.58	2.58	4.25

	Lab 3: Algal Groups				**Lab 4: Intro. to Plant Cells & Tissues**			
Group A	Q5a	Q5b	Q5c	Q5d	Q6a	Q6b	Q6c	Q6d
Student	Challenging	Interesting	Overwhelming	Stimulating	Challenging	Interesting	Overwhelming	Stimulating
1	5	4	4	6	4	4	4	4
2	4	6	4	6	3	6	3	6
3	3	2	1	2	5	3	3	3
4	5	3	3	4	4	5	3	4
5	6	6	5	5	6	7	5	5
6	4	4	4	5	4	5	3	4
7	5	5	6	4	3	3	4	3
8	5	6	5	6	3	5	4	5
Average	4.625	4.5	4	4.75	4	4.75	3.625	4.25
Group B	Q5a	Q5b	Q5c	Q5d	Q6a	Q6b	Q6c	Q6d
9	3	5	3	4	4	4	3	4
10	4	5	4	5	5	4	4	5
11	3	4	2	5	3	4	2	3
12	4	4	2	5	4	4	2	4
13	4	6	3	5	4	5	4	5
14	5	4	3	5	4	5	2	5
15	4	6	3	6	5	6	3	6
16	5	5	6	6	5	6	5	5
17	5	5	3	4	4	4	3	3
18	3	5	3	5	4	5	3	4
19	5	6	4	4	4	6	4	6
20	3	5	4	4	6	5	5	5
Average	4.00	5.00	3.33	4.83	4.33	4.83	3.33	4.58

	Lab 5: Bryophytes				Lab 6: Cryptogams			
Group A	Q7a	Q7b	Q7c	Q7d	Q8a	Q8b	Q8c	Q8d
Student	Challenging	Interesting	Overwhelming	Stimulating	Challenging	Interesting	Overwhelming	Stimulating
1	5	4	5	4	3	3	3	3
2	5	4	4	5	4	4	3	4
3	4	3	3	3	4	4	2	3
4	4	4	4	4	3	4	3	3
5	7	3	6	3	5	5	4	2
6	3	4	5	3	4	5	5	6
7	4	6	4	5	4	3	3	3
8	4	5	4	6	5	6	5	7
Average	4.5	4.125	4.375	4.125	4	4.25	3.5	3.875
Group B	Q7a	Q7b	Q7c	Q7d	Q8a	Q8b	Q8c	Q8d
9	5	4	4	5	5	4	3	5
10	4	4	4	5	5	4	5	5
11	2	5	2	2	3	5	2	3
12	4	4	2	4	4	5	4	4
13	3	3	3	3	5	5	4	5
14	4	5	2	5	4	5	2	6
15	3	6	3	6	4	5	4	6
16	6	4	6	6	5	6	4	5
17	3	6	3	5	3	5	2	5
18	6	3	5	5	3	5	3	4
19	5	4	4	4	4	6	4	4
20	4	3	4	4	5	5	4	5
Average	4.08	4.25	3.50	4.50	4.17	5.00	3.42	4.75

	Lab 7: Gymnosperms				**Lab 8: Angiosperms**			
Group A	Q9a	Q9b	Q9c	Q9d	Q10a	Q10b	Q10c	Q10d
Student	Challenging	Interesting	Overwhelming	Stimulating	Challenging	Interesting	Overwhelming	Stimulating
1	3	4	3	3	5	5	6	5
2	4	6	4	6	4	6	4	6
3	4	4	1	3	4	6	3	3
4	3	5	2	4	4	4	5	5
5	4	7	4	7	6	7	4	7
6	7	4	5	5	3	5	4	4
7	4	4	4	4	5	7	3	7
8	5	5	5	7	5	5	5	7
Average	4.25	4.875	3.5	4.875	4.5	5.625	4.25	5.5
Group B	Q9a	Q9b	Q9c	Q9d	Q10a	Q10b	Q10c	Q10d
9	4	5	4	4	5	5	3	4
10	5	6	6	5	5	4	5	5
11	3	5	2	4	4	6	4	4
12	5	5	4	4	4	5	4	4
13	5	6	5	6	6	6	5	6
14	4	5	2	5	4	6	3	6
15	3	6	4	6	4	7	3	7
16	5	6	5	4	4	6	3	5
17	3	4	2	5	3	5	4	5
18	5	5	4	5	6	5	4	4
19	5	6	4	5	4	7	5	6
20	4	6	4	5	6	5	5	4
Average	4.25	5.42	3.83	4.83	4.58	5.58	4.00	5.00

	Lab 9: Seed Germination				Lab 10: Woody Stems			
Group A	Q11a	Q11b	Q11c	Q11d	Q12a	Q12b	Q12c	Q12d
Student	Challenging	Interesting	Overwhelming	Stimulating	Challenging	Interesting	Overwhelming	Stimulating
1	3	5	3	4	3	4	3	3
2	4	7	3	7	3	5	3	5
3	4	6	3	3	3	3	2	2
4	2	3	2	3	3	4	3	4
5	5	7	3	7	5	7	4	7
6	2	4	5	5	6	6	5	4
7	4	7	3	4	4	5	4	3
8	5	7	5	7	4	6	4	7
Average	3.625	5.75	3.375	5	3.875	5	3.5	4.375
Group B	Q11a	Q11b	Q11c	Q11d	Q12a	Q12b	Q12c	Q12d
9	5	4	3	4	3	6	2	4
10	5	4	6	5	4	4	4	5
11	3	3	4	3	4	4	3	5
12	4	5	4	4	4	5	4	4
13	5	6	4	6	3	5	2	5
14	5	5	2	6	4	5	2	5
15	3	7	3	7	4	7	3	7
16	5	6	7	6	6	6	7	5
17	4	4	3	4	3	6	3	7
18	4	5	3	4	4	6	4	4
19	4	6	4	6	3	5	2	6
20	5	6	4	4	6	6	5	5
Average	4.33	5.08	3.92	4.92	4.00	5.42	3.42	5.17

	Lab 11: Leaves & Roots			
Group A	Q13a	Q13b	Q13c	Q13d
Student	Challenging	Interesting	Overwhelming	Stimulating
1	3	3	2	3
2	3	7	3	7
3	3	3	2	2
4	4	4	3	4
5	4	5	4	5
6	4	5	5	6
7	4	2	4	2
8	5	5	4	6
Average	3.75	4.25	3.375	4.375
Group B	Q13a	Q13b	Q13c	Q13d
9	4	5	3	4
10	5	4	5	5
11	3	5	3	4
12	4	4	4	4
13	4	3	3	3
14	4	4	2	5
15	3	7	2	7
16	5	7	5	5
17	3	3	3	3
18	3	3	3	4
19	4	4	4	4
20	4	5	4	4
Average	3.83	4.50	3.42	4.33

Group A	**Q14**
Student	
1	It would have made the lab more interesting and involved with additional projects. It would have provided a practical use for the information we were learning and stressed its importance. But it also might make the labs more stressful if you were simply adding it on to everything else.
2	The field trip to Lost River Cave was very intellectually stimulating, and I enjoyed seeing the species and examining the differences. Visual stimulation is vital to learning about plants, because seeing the differences will allow you to comprehend material more effectively. Also, live species are much more exciting than slides. Plus, enrolling in a lab course generally implies hands-on learning, and even if it didn't make the material easier, the opportunity for creative learning would have at least made the material more interesting.
3	No, I think the lab was very well planned and gave us enough information and skills to do the labs. I do think the lab example above would give an interesting look inside of plants we are probably more common with. I would enjoy doing that lab.
4	I believe a few more in depth experiments, like those in Thursday's lab would help understand the info better but would also make it more challenging.
5	Yes, I believe I would learn more and retain information from the labs better if more experiments, exercises, and case studies were incorporated. I know that with me, I can remember things better if stories are told. I wouldn't mind spending extra time in the lab if I learn something interesting that affects me every day. It helps me be a more informed individual in daily surroundings.
6	Yes
7	Yes. Experiments, exercises, and case studies make the material "come to life". It also makes it more interesting which makes you want to learn more. The hands on experiments like the dissection of the flower bring one dimension information to life and that greatly helps me to understand and relate to the information.
8	I do think that additional experiments, exercises, and case studies would have helped me learn the lab material better.

Group B				Tree Identification				Algal Water Contamination Case Study			
Student	Q14b	Q14c	Q14d	Q15a	Q15b	Q15c	Q15d	Q16a	Q16b	Q16c	Q16d
9	3	2	3	5	5	3	5	3	6	3	5
10	3	4	4	6	4	4	6	4	3	3	5
11	2	2	2	3	5	3	4	3	4	3	5
12	4	4	4	4	4	4	4	4	5	2	5
13	6	4	6	7	4	6	5	5	6	3	6
14	5	2	5	5	7	2	7	5	5	2	6
15	7	2	7	4	7	3	7	3	7	2	7
16	6	4	6	6	7	5	7	6	7	4	7
17	6	2	6	3	5	2	7	4	5	4	5
18	4	3	4	5	6	4	6	3	4	3	4
19	5	5	5	4	6	4	6	5	4	4	4
20	5	5	5	6	5	4	4	3	6	3	4
Average	4.67	3.25	4.75	4.83	5.42	3.67	5.67	4.00	5.17	3.00	5.25

Group B	Spore Proliferation				Seed Germination: Wisconsin Fast Plants				Genetically Modified Foods			
Student	Q17a	Q17b	Q17c	Q17d	Q18a	Q18b	Q18c	Q18d	Q19a	Q19b	Q19c	Q19d
9	4	3	3	3	5	5	6	4	5	5	4	5
10	4	3	2	4	2	3	2	2	4	4	4	5
11	2	1	1	2	2	5	2	4	3	3	2	3
12	2	4	1	4	1	5	1	4	5	6	3	6
13	3	4	2	3	4	6	3	5	5	6	3	5
14	4	5	2	6	5	7	2	6	5	5	2	7
15	3	7	3	7	3	7	2	7	3	6	3	7
16	6	6	4	5	6	6	4	6	4	7	5	6
17	3	2	2	2	2	4	3	3	5	4	4	4
18	2	2	1	2	5	4	4	3	5	4	5	3
19	5	4	4	4	3	6	3	6	5	7	6	7
20	4	5	4	5	4	6	4	4	6	5	6	6
Average	3.50	3.83	2.42	3.92	3.50	5.33	3.00	4.50	4.58	5.17	3.92	5.33

Group B	Forensic Botany				Medicinal Botany			
Student	Q20a	Q20b	Q20c	Q20d	Q21a	Q21b	Q21c	Q21d
9	4	4	4	4	3	5	3	4
10	3	4	3	4	3	2	2	4
11	5	5	3	5	2	4	2	4
12	3	6	2	6	4	7	2	7
13	6	7	4	7	2	4	1	3
14	6	7	2	7	5	5	2	7
15	4	7	3	7	2	6	2	6
16	5	7	4	7	3	6	3	5
17	4	7	2	6	2	4	1	4
18	4	7	4	5	4	5	3	3
19	4	6	5	6	3	6	2	6
20	5	6	5	5	4	6	4	4
Average	4.42	6.08	3.42	5.75	3.08	5.00	2.25	4.75

Group B	Q22: Do you feel that the additional experiments described above helped you learn better?
9	Yes, maybe not all of them but some did.
10	Yes in a way. Not so much the material we were tested on but on a more practical and technical use of botany.
11	Yes, active participation in the experiments required understanding of concepts involved, forcing the participant to learn or do poorly.
12	Yes, I believe so.
13	Yes. Just to look at slides and specimens is not nearly as engaging as a project. You must be actively involved in projects which helps put together the pieces of the "big picture." Viewing can be a passive/unengaging experience.
14	Yes, I believe the additional experiments really contributed to my enjoyment of the class, and helped me stay interested.
15	Yes, I thought it made the class more interesting.
16	Yes.
17	Some of the additional experiments did help me learn better. I think it would have helped if a couple were more closely related to what we were doing. For instance, the GMO experiment was interesting, but I think it took away from our actual lab material.
18	Most did help a lot. Others helped very little. (Some)
19	Yes, hands on activities always seem to help with the learning process.
20	I'm not sure if they helped me learn better, but they helped me learn about things I never knew about and helped me learn more about experiments.

Group B	**Q23: Did you find the additional experiments beneficial in retaining information for lab material? Explain.**
Student	
9	I didn't. I just remembered the lab, the experiments didn't help.
10	Maybe somewhat but most experiments weren't involving material we were studying.
11	Yes, seeing concepts illustrated in real life made them more memorable.
12	Well not really. However I still enjoyed them..
13	Yes. Like I said above, being active in the learning process helps piece together all the small facts into one cohesive, working idea. If all the little things can be related to one larger idea, I retain it much better!
14	Yes, although I was hoping for some questions on the final pertaining to the additional experiments themselves. But I suppose the credit was given in the credit for the assignment itself.
15	Yes, real world examples helped tie together key concepts.
16	Yes, they provided real world applications of what we learned. This required a better understanding of the material and made the applicable information more memorable.
17	Most of the additional experiments did help in retaining info for lab. I especially thought the algae case study was helpful.
18	Yes, because you could apply the interesting things you learned from the experiments.
19	Yes, I always seem to remember things I did rather than remembering things I read.
20	The only one that I felt helped me retain information for the lab assignments was the Wisconsin Fast Plant Experiment. I really liked doing the additional experiments, but I didn’t feel they helped with existing material.

Group A	Q15	Q16a
Student		
1	7	4
2	7	3
3	3	3
4	6	4
5	6	3
6	4	4
7	7	3
8	4	5
Average	5.5	3.625
Group B		
Student	Q24	Q25a
9	4	5
10	5	4
11	4	5
12	5	5
13	6	6
14	6	5
15	7	7
16	7	7
17	5	5
18	6	5
19	5	6
20	6	5
Average	5.50	5.42

Group A	Q16b: Traditional learning methods used in lab.
Student	
1	Made learning more boring. It was like every other typical lab and was monotonous in how it worked.
2	Traditional learning methods make learning harder only because it becomes too monotonous. All students are diverse learners, and it is a teacher's responsibility to incorporate different learning methods for each lab so that it may prove beneficial to each student.
3	I think it is sometimes harder to remember the slides just from looking at them and drawing them once.
4	Blank
5	I really had to ask a lot of questions during lab to really understand where things were located on slides. Some things were hard to grasp the first time being exposed, and I had to look at things several times before I felt really comfortable. I relied heavily on my book to look at slides and "reread" things.
6	Blank
7	Traditional methods don't do anything to enhance further understanding. Without knowing what we were missing our learning process seemed normal however, trying to learn was actually more difficult than it had to be.
8	The traditional learning methods used for this lab could be helped with some case studies, experiments, and exercises.

Group B	Q25b: Describe why you think the experiments we conducted in this course had the following effect on your learning.
Student	
9	It helped to fully understand and get more experience with what we were studying.
10	They did enhance my learning from a general botany aspect but not so much on what I had to learn. It seemed like extra material to learn.
11	The additional participation and thought involved reinforced topics.
12	They made the material more interesting.
13	They helped engage me in the lab - more so than viewing slides or herbarium specimens could have. The extra experiments also branched out a little to give you an idea of where this information you're learning about right now would be used out in the world or how it could translate into a career opportunity. (I like to know WHY something is important to learn.)
14	I think it helped keep my interest, and gave me more experiences/information to tie my lab knowledge to.
15	Again real world application
16	I explained in #23.
17	The additional experiments were interesting and some what related botany to real-life, which makes me realize I'm learning the material for a reason, (And it's not just busy work).
18	It helped a lot in the fact that it seemed like we had more freedom by learning this way instead of having to look at slides.
19	I am a visual person so anything hands on that I do I remember better.
20	It made learning a little bit easier just because I am more of a hands-on learner and feel that I remember things/material better if I'm actively participating with hands-on. It was a slight harder to learn just because there was so much to do in not enough time.

Group A	Q17a	Q17b	Q17c	Q17d	Q17e	Q17f	Q17g	Q17h	Q17i	Q17j	Q17k	Q18
Student												
1	2	1	4	3	3	4	4	6	5	5	4	7
2	1	3	3	5	5	4	6	7	7	6	7	7
3	2	6	3	3	3	3	3	4	3	3	3	7
4	1	6	4	5	4	4	6	6	5	4	4	7
5	1	7	3	6	3	5	7	7	7	7	6	6
6	3	3	3	3	3	4	4	4	4	4	4	5
7	1	7	7	1	1	1	1	7	7	1	1	7
8	3	7	5	5	5	6	6	6	7	6	6	4
Average	1.75	5	4	3.875	3.375	3.875	4.625	5.875	5.625	4.5	4.375	6.25
Group B												
Student	Q26a	Q26b	Q26c					Q26d	Q26e	Q26f	Q26g	Q27
9	5	3	7					2	4	4	4	6
10	5	6	3					3	2	2	2	5
11	1	3	4					3	4	5	4	6
12	2	3	3					4	4	4	4	7
13	7	2	5					6	4	6	3	5
14	3	7	5					6	5	5	5	6
15	4	5	4					5	3	5	3	6
16	5	6	7					5	6	4	5	7
17	4	5	6					3	4	6	6	7
18	4	7	5					3	4	4	3	7
19	3	5	4					5	6	5	5	5
20	4	3	5					4	5	5	5	4
Average	3.92	4.58	4.83					4.08	4.25	4.58	4.08	5.92

Group A	Q19a	Q19b
Student		
1	2	7
2	2	7
3	5	6
4	4	6
5	7	7
6	4	4
7	7	7
8	5	4
Average	4.5	6
Group B		
Student	Q28a	Q28b
9	5	6
10	5	7
11	7	6
12	7	7
13	7	7
14	6	5
15	6	6
16	4	7
17	2	6
18	7	7
19	4	5
20	7	7
Average	5.58	6.33

Group A	**Q20: Describe what you liked <u>most</u> about this course?**
Student	
1	What I liked most was the teacher/student contact. You were very involved in every lab which made them better.
2	There were two things I liked most about the course: the teacher (because she enjoyed what she was teaching) and the hands-on activities, like the field trip or the dissection of the flower.
3	I enjoyed the tree classification I just wish we had done it after learning all the terms and what we were supposed to be looking at.
4	How broad it is, great background for new botanists.
5	I really liked the material we covered from the semester. Some of the material I learned from this class will definitely help me in the future and in my area of interest.
6	Planting sunflowers.
7	The bioluminescent thing was amazing. Lost River Care volunteer project was a great opportunity. I liked dissecting the flowers and planting sunflowers. Actively helpful lab instructor!
8	The Lost River Cave and tree identification was my favorite lab.

Group B	Q29: Describe what you liked most about this course?
Student	
9	The pre-lab notes and additional notes to the lab were very beneficial and taught a lot.
10	The instructor was very reliable and extremely helpful when needed.
11	The learning environment was relaxed and pleasant.
12	The instructor was more helpful than any I've ever had in a lab before.
13	I liked learning about the angiosperms (flower dissection) the most and growing our own plants to keep. I still have mine and I enjoy it because I grew it and learned about it. Colorful Pictures! They looked like the slides so I has no problems finding what I was looking for (most of the time) under microscope.
14	Very good, understanding teacher, who could easily communicate with me and explain things when I was having problems or didn't understand.
15	I liked the extra experiments that were interesting.
16	We were able to apply much of what we learned. This made the topics more interesting and memorable.
17	I liked just about everything. This class (along w/ lecture) has encouraged me to study plants and soils in the future.
18	Getting the notes for each lab during the second half of the semester.
19	I liked the tree identification, the forensic botany, and the medicinal botany the most.
20	I liked our lab teacher. It makes all the difference in the world how good your teacher is. But as for as the course goes I liked getting to grow our own plants and looking at specimens under the scope.

Group A	**Q21: Describe what you liked least about this course?**
Student	
1	The lessons on the microscope was my least favorite since almost every biology lab does it.
2	The only thing I disliked about the course were the slides… especially when better visual representation was in the textbook.
3	The labs that just had drawings & labeling.
4	The old lab manuals (Black & White).
5	I hated that we really didn't get to conduct experiments. We basically looked at slides and live specimens.
6	Algae lab.
7	I absolutely hated drawing things I was looking at under the microscope and labeling it.
8	The microscope lab was my least favorite lab.

Group B	Q30: Describe what you liked least about this course?
Student	
9	I didn't enjoy the experiment on genetically modified food. Other than that the class was run fair.
10	The extra experiments.
11	Spending so much time at the microscope was very tedious.
12	I hated the quizzes!
13	Probably the plant identification - would have been better if we have studied leaf types before doing the lab. I would have liked to record the growth of a plant we could take home at the end of a project instead of the Petri dish ones- sorry but I didn't really like that one.
14	My seat was squeaky and uncomfortable. I also couldn't adjust the height of it. Please buy new seats.
15	duplicate slides
16	Sometimes, we didn't have enough class time to cover some sections as in-depth as they need to be.
17	I wasn't a big fan of the food experiment. Our results were hard to read and I don't think I care so much if my food was produced from modified plants.
18	Having to go through the whole microscope lab.
19	I didn't really like the algae lab.
20	I disliked having to go into so much cellular detail under the microscope. I found this really overwhelming and liked having some things a bit more macro.

Group A	**Q22: Do you suggest further changes for this course? Describe.**
Student	
1	More interactive labs with more than drawing off slides, but not necessarily getting rid of all the drawing.
2	I think more hands-on activities and investigative procedures would be beneficial.
3	I think it was well taught and well prepared.
4	new manuals, more stuff related to applying this knowledge in real life (tree identification, etc.)
5	I would suggest doing other activities rather than look at slides, label, and see specimens, I would suggest other activities, experiments, field trips, colored pictrues, and world examples.
6	No, but a more advanced in door growing section would be nice.
7	More hands-on activities.
8	I like the traditional lab method. But I feel it would be more interesting to add some case studies, exercises, and experiments.

Group B	**Q31: Do you suggest further changes for this course? Describe.**
Student	
9	Maybe takeout the genetically modified food experiment.
10	Overally this course was well constructed and very well instructed. There isn't much I would change.
11	More outdoor labs would have broken up the monotony.
12	Not really.
13	I would have enjoyed the plant identification more if we could have somehow covered types of leaves and cones BEFORE trying to identify trees by those very features in a real setting. I honestly don't know that I learned anything from that and I'm pretty sure my IDs were wrong.
14	Perhaps it would be good to invest in some computer based programs, that would allow students to easily see/label figures and images outside of class. It would be easier, yes, but that's the point.
15	more experiments and field trips outdoors
16	Possibly extend class time.
17	I like it a lot.
18	Not really because it was overall a very productive course.
19	Don't try to pack too many experiments in one day.
20	Only less emphasis on the micro side of things. I realize it’s a lab and you have to use the microscope.

Group A	Q23a	Q23b	Q23c	Q23d	Q23e	Q23f	Q24a
Student							
1	6	5	3	6	4	2	yes
2	6	7	7	7	4	6	sometimes
3	5	4	5	5	5	1	yes
4	5	6	4	7	4	6	sometimes
5	7	7	7	7	7	7	sometimes
6	3	3	3	3	3	4	no
7	3	7	5	7	1	4	yes
8	4	5	6	5	3	5	sometimes
Average	4.875	5.5	5	5.875	3.875	4.375	
Group B							
Student	Q32a	Q32b	Q32c	Q32d	Q32e	Q32f	Q33a
9	5	4	5	5	5	3	sometimes
10	4	5	3	6	3	2	sometimes
11	4	4	4	5	4	3	sometimes
12	4	6	4	7	1	1	sometimes
13	6	5	7	7	7	3	yes
14	5	5	5	4	5	3	yes
15	5	7	6	6	3	7	yes
16	6	6	6	6	4	3	sometimes
17	6	6	6	7	6	7	yes
18	5	5	4	6	4	6	yes
19	5	5	5	6	7	7	yes
20	5	4	5	6	6	2	yes
Average	5.00	5.17	5.00	5.92	4.58	3.92	

Group A	**Q24b: Did working in groups help you learn lab material significantly?**
Student	
1	Yes, because you heard other people's opinions to figure things out.
2	Not really, I enjoyed working alone.
3	Yes.
4	Yes.
5	Blank.
6	I thought I learned more by myself at my own pace.
7	I actually prefer working alone. I very much appreciate having the choice to work in groups or alone.
8	Yes, we worked together in tree identification.

Group B	**Q33b: Did working in groups help you learn lab material significantly?**
Student	
9	No.
10	If I couldn't understand I was able to receive help from a partner.
11	Blank.
12	No. It just helped me get out of the lab quicker.
13	Yes! Working with someone else who is in the same class as you are helps me understand material better. I can get quick, accurate answers to my questions rather than waiting on an instructor to answer EVERY question I have. (Keeps instructor free for only the really hard questions).
14	Yes, but I worked with a close friend I already knew well, so we were able to discuss it together a lot. The extra discussion helped me a lot.
15	yeah, it made it go faster too
16	Not significantly. It did lessen the time needed to work, so more learning could be accomplished without being rushed.
17	I think so. Things I wouldn't feel comfortable asking the lab instructor, or if the lab instructor is busy w/ another student, I could turn to my group for help.
18	Yes, because if you didn't understand something then they could explain it in more simple terms.
19	Yes, if I didn't know what something was I had someone right there to ask.
20	Working in groups helped me learn much more because if I didn't understand something. Usually someone in my group could explain it to me.

Group A	Q25	Q26	Q27	Q28
Student				
1	4	2	7	6
2	6	7	7	7
3	4	1	6	4
4	5	5	7	5
5	7	7	7	7
6	5	6	4	5
7	7	4	7	7
8	6	6	7	7
Average	5.5	4.75	6.5	6
Group B				
Student	Q34	Q35	Q36	Q37
9	5	4	7	7
10	5	5	7	6
11	3	5	6	6
12	6	6	7	7
13	6	6	7	7
14	6	7	7	7
15	6	7	7	7
16	6	6	7	7
17	7	7	7	7
18	6	6	6	7
19	6	5	7	6
20	5	4	7	5
Average	5.58	5.67	6.83	6.58

Group A	**Q29: Would you suggest this course to another student? Why?**
Student	
1	Yes, because it's fun and many things were interesting and unique to only botany. And it had a great lab teacher.
2	Yes, simply because it's fun and interesting.
3	Yes, it is straight to the point on what you need to know and what you should have learned.
4	Yes, good starting place for understanding plants. Great lab instructor.
5	Yes, I would definitely recommend this class to another student. I believe students should understand more about plants because they have importance and value. I think that this class will help them to understand the importance and value of plants.
6	Yes, it was fun.
7	Yes, as long as they were interested in plants. This course has been a good intro into a field I wanted to know more about. I feel confident in sharing the info I have gained and have a strong desire to learn more. I think a student should feel that way after every class.
8	This course will allow you to understand the importance of plants.

Group B	**Q38: Would you suggest this course to another student? Why?**
Student	
9	Yes.
10	Yes as long as their interest pertained to plants.
11	Yes, with caution regarding the tedium.
12	Yes!
13	I would tell other people who need science credit to take this course if they wanted to learn more about plants and how they "work."
14	Yes, I certainly would. I would be severely disappointed if my teacher received a poor rating on this, because as a future teacher myself, she is doing things exactly as I would want.
15	yeah
16	Definitely.
17	To everyone!
18	Anyone that is a pursueing a career in some botanical field or if you will be working in wooded areas, for more knowledge of plants.
19	Yes.
20	Yes, but only if they are a good student and ready to put the time and effort into it.

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