Addressing *Vision & Change* in Undergraduate Biology Education: Two Case Studies

THESIS

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Abstract

The American Association for the Advancement of Science (AAAS) released *Vision and Change in Undergraduate Biology Education: A Call to Action* in 2009 and *Vision and Change in Undergraduate Biology Education: Chronicling Change, Inspiring the Future* in 2013. Both of these reports urged educators to employ active learning and inquiry-based pedagogical methodologies, to make the subject of biology less abstract to students by demonstrating clearly connections to the real world, and to continue data driven discipline-based education research to guide and inform instructional practices at the university level. To address these recommendations of the AAAS, I conducted two distinct biology education research studies in three separate biology classes: BIO 1101: Introductory Biology for non-majors, EEOB 2210: Ohio Plants, and EEOB 3320: Organismal Diversity at The Ohio State University.

In order to address the AAAS recommendation to make biology less abstract to undergraduate students and to continue to incorporate effective pedagogical strategies, I conducted a study in BIO 1101: Introductory Biology for non-majors that focused on effectively communicating the concept of biodiversity. For this study, I developed a new biodiversity exercise and a survey instrument with both objective and Likert-type questions to determine the exercise’s effect on student learning. When compared to students who completed the traditional biodiversity exercise utilized in the class (mean gain = 0.41 ± 0.62), students who completed the new biodiversity could name more
ground-dwelling invertebrates (mean gain = 0.79 ± 1.24). Additionally, students who completed the new exercise had significant shifts in agreement on the biodiversity survey question cluster (questions 48 through 50) about the benefits of fieldwork and hands-on activities on their learning. The results of both the objective questions and Likert type questions together indicate that my new biodiversity exercise has a more positive impact on student learning than the traditional biodiversity exercise which lacked substantive fieldwork components and clear inquiry based pedagogical methods.

With AAAS’ call to perform assessments on learning and use the results to enhance student learning, I conducted my second study on the evaluation of mobile learning technology—specifically the Apple iPad—because informative empirical studies demonstrating their efficacy lag in the education literature. I conducted this study in two courses, EEOB 2210: Ohio Plants and EEOB 3320: Organismal Diversity. I sought to determine the effect of the presence or absence of iPads on student learning outcomes by examining student products resulting from iPad usage in two contexts: as digital field notebooks and digital sharing devices in the classroom. Additionally, I sought to determine the role of familiarity (i.e., level of comfort) with iPads on student learning outcomes by administering pre- and post-technology surveys to students. All aspects of my study revealed that the use of iPads does not affect student outcomes positively or negatively. Students using iPads as field notebooks and sharing devices did not document more raw data and there was no subsequent relationship with scores on summative assessments. This result is consistent across student familiarity and student perception of benefits of iPads.
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Chapter 1: Introduction

In 2009, the American Association for the Advancement of Science (AAAS) released *Vision and Change in Undergraduate Biology Education: A Call to Action*, with a recommendation that instructors employ both inquiry-based and student-centered, active learning methodologies in undergraduate biology courses (AAAS, 2009). In addition, a recommendation was made to make biology less abstract by clearly demonstrating the connections to the real world, particularly in non-majors introductory courses, as these courses are often the only exposure to the sciences that some college students will have (AAAS, 2009). A follow-up report: *Vision and Change in Undergraduate Biology Education: Chronicling Change, Inspiring the Future* (AAAS, 2013) stated that “active learning is no longer a novelty, but rather an expectation” and placed an emphasis on the continued need for data driven discipline-based education research to guide and inform faculty on changing their teaching methods (AAAS, 2013). Indeed, many researchers have evaluated active learning (Freeman et al., 2014; Haak, David C., HilleRisLambers, J, Pitre, Emile, Freeman, 2011) and inquiry-based teaching methodologies (Goldey et al., 2012; Lord & Baviskar, 2007; S. Rissing & Cogan, 2009; Spiro & Knisely, 2007; Timmerman, Strickland, & Carstensen, 2008) and found them to be effective in improving learning outcomes.
While the AAAS has made recommendations and calls for change, educators still face challenges in the implementation of recommendations due to lack of a clear model to facilitate change (D’Avanzo, 2013). In addition, students often misunderstand both science and biology as a simple accumulation of facts. This “accumulation of facts” view should not surprise educators given that many undergraduate biology courses still focus on the memorization of facts rather than higher-order thinking (Lord & Baviskar, 2007; Momsen, Long, Wyse, & Ebert-may, 2010). Additionally, an increased focus on teaching to the Medical College Admissions Test (MCAT) often truncates the curriculum so that topics such as organismal biology and biodiversity do not receive adequate coverage (S. W. Rissing, 2013). While educators still advocate for and develop new methods for teaching the concept of biodiversity (Awasthy, Popovig, & Linklater, 2012; Davis-Berg, 2011; McCoy, McCoy, & Levey, 2004; Richardson & Hari, 2008; Thiet, 2014), utilizing local, urban biodiversity, as in this thesis, allows students to experience and investigate biodiversity firsthand (Chapter 2).

Another recommendation of the AAAS was to perform quantitative assessments of learning and use the results to enhance student learning. One approach would be the evaluation of mobile learning technologies—such as the Apple iPad—which have been broadly implemented in undergraduate courses in math, chemistry, and anatomy. While iPads have been used in these courses in a variety of ways, informative empirical studies demonstrating their efficacy lag in the education literature. Most studies document the use of iPads as a replacement technology (Hesser & Schwartz, 2013; Mayfield, Ohara, & O’Sullivan, 2013) or student perceptions of the benefits of using iPads on their learning (George et al., 2013; Gong & Wallace, 2012; Rossing, Miller, Cecil, & Stamper, 2012).
For this reason, I chose to quantitatively examine specific aspects of Apple iPad usage to test how it affected learning outcomes in the biology classroom (Chapter 3).

In this thesis, I focus on effective biodiversity education and implementation of mobile technology in the biology classroom at The Ohio State University. I detail the development, implementation, and evaluation of a new inquiry-based biodiversity exercise in an introductory biology for non-majors course, BIO 1101, within The Center for Life Science Education (CLSE) (Chapter 2). I examine the implementation and evaluation of iPads as digital field notebooks and digital sharing devices in two biology courses within the Department of Evolution, Ecology, and Organismal Biology (EEOB)—EEOB 2210: Ohio Plants and EEOB 3320: Organismal Diversity (Chapter 3). Finally, I will summarize the results and overall conclusions from my two studies and provide recommendations for further implementation and evaluation of inquiry-based biodiversity exercises and appropriate application of mobile learning technology in the biology classroom (Chapter 4).
Chapter 2: Improving Biodiversity Education for Undergraduate Biology Students

Introduction

Recent guidelines and recommendations from the National Research Council (NRC) state the need to convey information regarding conservation efforts, trends in global levels of biodiversity, and human impacts on biodiversity to K-12 students. The Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas suggests that an important learning goal for high school students to understand is that “Ecosystems with a wide variety of species—that is, greater biodiversity—tend to be more resilient to change than those with few species” (NRC, 2012). Additionally, the NRC recommends that college students understand how and why both “biological systems and organisms are extraordinarily diverse” and that “Humans, as well as many other species, are members of multiple ecosystems. They have the capacity to disrupt or preserve the ecosystems upon which they depend” (NRC, 2003).

Current species loss rates indicate an ongoing mass extinction event (Barnosky et al., 2011) and suggest a need to refocus conservation efforts. Reviving the declining study of natural history (Schmidly, 2005) could raise interest in conservation issues and lead to important revisions in conservation strategies. Educators cannot begin to focus on conservation efforts without first enabling students to develop an understanding and
appreciation for the biodiversity around them. Fostering that understanding has become especially challenging as a result of continually increasing student dissociation from nature (Awasthy et al., 2012; Johnson & Catley, 2009).

To encourage student awareness of biodiversity, I developed an inquiry-based field exercise that promotes direct interaction with local environments. While typical undergraduate biology education focuses on the memorization of facts rather than higher-order thinking (Lord & Baviskar, 2007; Momsen, Long, Wyse, & Ebert-May, 2010), inquiry-based activities foster higher-order learning skills (Goldey et al., 2012) and may produce greater learning gains (Rissing & Cogan, 2009; Timmerman, Strickland, & Carstensen, 2008).

Additionally, directly interacting with the environment by collecting organisms may promote an increased understanding of biodiversity (Scott et al., 2011). For example, upon assembly of an organismal collection in an introductory biology class, students recognized that biodiversity encompasses more taxa than just the chordates (White, 2009). In my study, I wished to determine student awareness of ground-dwelling invertebrate biodiversity, to understand student attitudes towards fieldwork and hands-on activities, and to understand student perceptions about their ability to make connections between their study of biology and their everyday interactions with organisms.

I hypothesized that if students complete an inquiry-based fieldwork biodiversity exercise in which they collect their own specimens, they will:

a) Develop a better understanding and awareness of ground-dwelling invertebrate biodiversity by naming more ground-dwelling invertebrates found on campus after completion of the exercise,
b) Perceive that fieldwork and hands-on activities have a beneficial impact on their learning by increased agreement with Likert-type questions relating to the benefits of fieldwork,

c) Increase their ability to make real world connections to their study of biology by a shift from novice-like to more expert-like opinions on a real world connections cluster of questions from CLASS-Bio (Semsar, Knight, Birol, & Smith, 2011).

I hypothesized that they will do this to a greater degree than will students who complete a traditional biodiversity exercise lacking extensive inquiry- and fieldwork-based components. To test these hypotheses, I compared the impact of a newly developed inquiry-based fieldwork biodiversity exercise with that of a traditional biodiversity exercise in BIO 1101: Introductory Biology for Non-Majors at The Ohio State University (OSU).

Materials and Methods

*New Biodiversity Exercise*

For my study, I developed and implemented a new inquiry-based biodiversity field exercise in eight laboratory sections of BIO 1101: Introductory Biology for Non-Majors in the Spring 2015 semester. Six other laboratory sections completed a traditional biodiversity exercise, which also incorporated some minor fieldwork activities, but lacked an inquiry-based format. I illustrate the differences between the inquiry and
fieldwork components of the traditional biodiversity exercise and my new biodiversity exercise in Table 2.1.

The new biodiversity exercise occurred over two laboratory sessions, whereas the traditional exercise occurred over one. The traditional exercise included a field trip where students collected items that they perceived as “living.” Once students returned from the field trip, they sorted through their collected specimens and added to them to similar pre-collected (from previous terms) and preserved lab specimens. After sorting through all of their specimens, they spent the remainder of the lab session determining how to best categorize these specimens. During the first session for the new biodiversity exercise, students went into the field, took basic field notes (weather conditions, habitat descriptions, etc.), gathered substrate samples, and placed those samples in Berlese funnels (explained below). During the second session, students sketched any organisms that they discovered after extraction of the substrate sample with their Berlese funnels, attempted to identify those organisms with pocket field guides that I developed, and compared results with their classmates (see Appendix C and D for the student version of the exercise and instructor version of the exercise, respectively).

I reviewed the basic learning objectives and procedures of the traditional and new biodiversity exercises with the course teaching assistants (TAs) during their weekly staff meetings before they administered the exercises. I did this to ensure that TAs were comfortable administering the exercises and utilizing the associated PowerPoint presentations (see Appendix E and F for week 1 and week 2 PowerPoint slides, respectively).
The Berlese Funnel Apparatus

My new exercise focused on the usage of Berlese funnels for the ecological sampling of soil fauna. Entomologists regularly use Berlese funnels to survey ground-dwelling microarthropods including mites, small spiders, insects, etc. (Triplehorn & Johnson, 2005). I constructed Berlese funnels from the top halves of two-liter plastic bottles (Figures 2.1, 2.2). Inside the bottles, I placed 10.0 cm × 10.0 cm squares of wire mesh with 2.0 mm wide openings that allowed small arthropods and other invertebrates (but not large pieces of substrate) to reach the openings of the bottles and to fall into Styrofoam cups placed below. The Styrofoam cups contained a 70% denatured ethanol solution (Fisher Scientific, Columbus, OH)—the optimal ethanol concentration for preservation of arthropods (Oman, 1952).

To force invertebrates out of the substrates, students placed the funnel apparatus under incandescent bulbs. The light bulbs heated and desiccated the substrates, which led to arthropods and other ground-dwelling invertebrates attempting to escape downwards and falling into the ethanol solution.

Assessing Exercise Efficacy

To evaluate the efficacy of my new biodiversity exercise, I developed both objective and Likert-type questions to measure three distinct constructs (Table 2.2) on pre-exercise and post-exercise surveys. My pre- and post-exercise surveys were identical except for question 51, which only appeared on the post-exercise survey. I administered the first versions of our pre-post surveys to students in EEOB 3320: Organismal Diversity, an OSU course that piloted my new biodiversity exercise during the Spring
2014 and Summer 2014 semesters. I subsequently revised the surveys for use in this study. Refer to Appendix B for the full pre-post survey instruments.

The constructs measured by my surveys corresponded with the learning goals of my new exercise:

• To discover the abundant diversity of arthropods and other ground-dwelling invertebrates on the OSU campus

• To recognize differences between arthropods and other ground-dwelling invertebrates discovered on the OSU campus

• To experience biology and natural history as processes of discovery through basic fieldwork

I designed my objective questions to measure student understanding and recognition of the relative abundance of arthropods and other ground-dwelling invertebrates. I designed several Likert-type questions to measure student attitudes towards the efficacy of the fieldwork activities incorporated into their biology classes with regard to their learning success. Additionally, I used the entire CLASS-Bio instrument developed by Semsar, Knight, Birol, & Smith (2011) to understand student thinking about the nature of biology (NOB) as compared with expert thinking in conjunction with my survey. Although I was only interested in student responses to the “real world connections” cluster of questions from that instrument, I used the entire CLASS-Bio instrument because the developers validated it as a whole and noted that educators can simply examine the clusters of questions in which they are interested. The “real world connections” cluster of questions measures the ability of students to make connections between their biology coursework and their daily interactions with
organisms. In addition to this cluster, I developed a Likert-type question—question 14: “I do not feel that I have many interactions with biodiversity in my daily life”—to measure student perceptions about their connections with biodiversity.

For pre-post assessment objective questions 10-13, I developed specific coding schemes for student answers. These coding schemes allowed me to perform statistical analyses to determine whether any significant changes in student understanding and recognition of arthropod and other ground-dwelling invertebrate diversity occurred after completion of either the traditional or new biodiversity exercise.

Survey question 10 asked students to “List five (5) different animal species (common names are acceptable) that you can expect to find around OSU’s campus. As an example to help understand the format: instead of writing ‘mammal’, write ‘red kangaroo’ or ‘Macropus rufus’.” In this question, I used an example of a species that students would not find on campus. By doing this, I avoided prompting the students to provide species that were discoverable with their funnel apparatus. This question was adapted from White (2009) and modified for my study. I used this question to measure student understanding and awareness of the relative abundance of arthropod and other ground-dwelling invertebrates before and after completion of either the traditional or new biodiversity exercise. I coded student answers as “Vertebrate”, “Soil Invertebrate”, “Other Invertebrate”, or “Other” (Table 2.3). We coded organisms as “Soil Invertebrate” if they were discoverable with my modified version of the Berlese funnel apparatus (Figures 2.1 and 2.2).

Survey question 11 asked students “What kinds of locations on OSU’s campus might you expect to find the most animal diversity? (List 3 locales and describe briefly—
less than 5 words—why you believe each is a good locale for that diversity.)” To determine whether students understood that ground-dwelling invertebrate diversity is greater than charismatic vertebrate diversity on the OSU campus, I coded answers as arthropod locales (ART) or non-arthropod locales (NART) (Table 2.4). To receive an ART code, students must have specifically mentioned insects or “bugs” in their justification for choosing a location. While I used ART as a proxy for general ground-dwelling invertebrate diversity awareness, I coded answers as arthropod and non-arthropod locales because students mentioned only arthropod, plant, and vertebrate groups in their justifications. Since arthropods comprise the majority of multicellular animal biodiversity on Earth with at least 751,000 described insect species and 121,161 other described species (Wilson & Peter, 1988), I assumed that arthropods have the greatest species richness on the OSU campus.

Survey question 12 asked students “Which group(s) of animals do you think is(are) most abundant (i.e., greatest number of animal species per group in many of the world’s ecosystems)?” to determine whether students understood that arthropod diversity makes up the majority of global multicellular animal biodiversity. I coded the responses into six categories: “Human” (HU), “Non-Human Vertebrate” (NHV), “Non-Arthropod Invertebrate” (NAI), “Insect” (INS), “Arthropod” (ART), and “Other” (O). I counted INS and ART as correct and the other four codes as incorrect (Table 2.5).

Survey question 13 asked students to rate on a scale from 1 (strongly disagree) to 3 (neutral) to 5 (strongly agree) their agreement with the statement “There is more macro-diversity contained on the branches of a tree (e.g., pine tree) than there is non-bacterial micro-diversity on or in the soil below that tree.” We used this question in conjunction
with questions 10 and 11 to determine whether students recognized that the bulk of animal diversity on the OSU campus is located within soil and/or on the ground rather than in areas inhabited by the charismatic vertebrates often observed on campus by students. I coded 3 (neutral), 4 (agree), and 5 (strongly agree) as incorrect and 1 (strongly disagree) and 2 (disagree) as correct (Table 2.6).

During the implementation of my study, each laboratory section of BIO 1101: Introductory Biology for Non-Majors had approximately 24 students and met once a week for approximately three hours. The course had a separate lecture component that met for three 55-minute periods each week. Students in both the control and treatment sections completed surveys two weeks prior to completion of the assigned exercises and two weeks after completion of the exercises. Students received course credit of 5 points per survey (for a total of 10 course points). The course instructor required all students to complete the pre- and post-exercise surveys; however, only 154 students (54.4%) completed the pre-survey and 236 students (83.3%) completed the post-survey. While 283 students initially enrolled in the course during the Spring 2015 semester, the number of student responses used in my analysis was lower because I started with the number of students who completed both the pre-and post-survey: 154. Additionally, I omitted the responses of students who:

- Did not provide consent to participate in the study; 18 students
- Provided non-serious answers (e.g., responded with “dinosaurs” or “kangaroos” to question 10 on the survey); 5 students
- Failed to select “Agree”, not “Strongly Agree”, on question 42: “We use this statement to discard the surveys of people who are not reading the questions. Please select agree (not strongly agree) for this question to preserve your answers.”; 16 students
• Dropped out of the course; 7 students

After removal of these responses, I had 62 student survey respondents who completed the new exercise and 46 student survey respondents who completed the traditional exercise. Ultimately, I evaluated the answers of 108 of the 283 (about 37.8%) students initially enrolled in the course.

The Office of Responsible Research Practices at The Ohio State University determined that my initial protocol (the piloting of my new exercise and assessment tools in EEOB 3320: Organismal Diversity) was exempt from Institutional Review Board (IRB) review (Protocol Number: 2014E0006). I have provided the full timeline and brief description of the development process for both the biodiversity exercise and the pre-post survey instrument (Appendix Table A.1). The Behavioral and Social Sciences IRB approved subsequent protocols for the revision of my new exercise and assessment instruments in EEOB 3320: Organismal Diversity and the implementation of my new exercise in BIO 1101: Introductory Biology for Non-Majors (for this study) for expedited review (Protocol Number: 2014B0191).

Data analysis

For all analyses, I used an $\alpha = 0.05$ and reported p-values as the results of two-tailed tests. We performed all pre-post question analyses with the Statistical Package for the Social Sciences (IBM Inc. Columbus, OH.).

Once we coded students answered into counts for questions 10 and 11, I performed paired $t$-tests. For these questions, I tested the null hypotheses that a) the mean number of ground-dwelling invertebrates named (question 10) and b) the mean number of
arthropod locales (coded as ‘ART’) listed (question 11) did not differ before and after completion of either exercise. Once I coded student answers as correct or incorrect for questions 12 and 13, I tested the null hypotheses that for each question the proportions of correct answers did not differ before and after completion of either exercise. I used McNemar’s test for paired proportions—a statistical test that educators have used to determine differences in pre-post test score proportions—to evaluate questions 12 and 13, (Adedokun & Burgess, 2012; Ding & Liu, 2012).

Since the data for Likert-type questions 14, 47, 48, 49, and 50 did not meet the assumptions of normality, I performed nonparametric Wilcoxon signed-rank analyses (Lovlace & Brickman, 2013; Ramsey & Schafer, 2013). With the Wilcoxon signed-rank tests, I tested the null hypotheses that the population mean ranks did not differ before and after completion of either exercise. Additionally, I report effect sizes, r, with the Wilcoxon signed-rank analyses by using the following formula:

\[ r = \frac{Z \text{ score}}{\sqrt{N}} \] [2.1]

where N equals the sample size times two (Field, 2005). Effect sizes are small (0.1), medium (0.3), or large (0.5) (Cohen, 1988).

In Appendix Table A.2, I also present these data with parametric analyses (e.g., paired t-tests), as many researchers have done in educational studies (Brownell, Kloser, Fukami, & Shavelson, 2010; Clason & Dormody, 1994; Norman, 2010; Rissing & Cogan, 2009). For question 51, I report the percentage of “favorable” ratings by students, as I had no paired question for comparison.
Results

**Construct 1: Questions 10, 11, 12, and 13**

To determine student understanding and recognition of arthropod and other ground-dwelling invertebrate diversity, I examined the counts of ground-dwelling invertebrates that students named on question 10 from the pre-post surveys.

Before the traditional biodiversity exercise (n = 46), students named an average of 0.13 ± 0.34 ground-dwelling invertebrates. After the traditional biodiversity exercise, students named an average 0.54 ± 0.59 ground-dwelling invertebrates. I found that there was a significant difference in the average number of ground-dwelling invertebrates named by students before and after the traditional biodiversity exercise (paired t-test, $t_{45} = -4.54$, $p < 0.001$; Figures 2.3 and 2.4).

Before the new biodiversity exercise (n = 62), students named an average of 0.27 ± 0.61 ground-dwelling invertebrates. After the new biodiversity exercise, students named an average of 1.06 ± 1.15 ground-dwelling invertebrates. I found that there was a significant difference in the average number of ground-dwelling invertebrates named by students before and after the new biodiversity exercise (paired t-test, $t_{61} = -5.01$, $p < 0.001$; Figures 2.3 and 2.4).

To compare the changes in the average numbers of ground-dwelling invertebrates named by each group, I calculated the gains in the mean numbers of ground-dwelling invertebrates named by students on question 10. I performed Levene’s test of equal variances for these groups ($F = 10.756$, $p = 0.001$). Since the variances of the gains in the mean numbers of invertebrates named were not equal between students who completed
the traditional biodiversity exercise and the new exercise, I performed an independent T-test without the assumption of equal variances. I found that the mean gains in ground-dwelling invertebrates were significantly different between students who completed the traditional exercise (mean gain = 0.41 ± 0.62) and the new exercise (mean gain = 0.79 ± 1.24) (independent t-test, t_{94,187} = 2.07, p = 0.041; Figure 2.5).

Question 11 asked students to provide locations in which they would expect to find the most animal diversity. I evaluated the mean numbers of arthropod (ART) locales named.

Before the traditional biodiversity exercise, students named an average of 0.07 ± 0.26 ART locales. After the traditional biodiversity exercise, students named an average of 0.09 ± 0.36 ART locales. I found that there was no significant difference in the average number of ART locales named by students before and after the traditional biodiversity exercise (paired t-test, t_{43} = -0.33, p = 0.743).

Before the new biodiversity exercise, students named an average of 0.10 ± 0.44 ART locales. After the new biodiversity exercise, students named an average of 0.10 ± 0.34 ART locales. I found that there was no significant difference in the average number of ART locales named by students before and after the new biodiversity exercise (paired t-test, t_{58} = -0.33, p = 1.000).

Question 12 asked students to provide the animals groups that they thought were most abundant (i.e., greatest number of species). I evaluated the percentages of students with answers scored as ‘correct’—answers coded as ‘Arthropod’ or ‘Insect’—before and after completing both the traditional and new biodiversity exercises. I found that the differences in the proportions of correct answers were statistically significant for students
who completed both the traditional biodiversity exercise (24.4% to 53.3%; McNemar’s test for paired proportions, \( p = 0.003 \)) and the new biodiversity exercise (28.3% to 66.6%; McNemar’s test for paired proportions, \( p < 0.001 \); Figure 2.6). For both the traditional and the new exercises, I found that the proportions of students who answered correctly pre-exercise differed significantly from the proportions of students who answered correctly post-exercise based on testing with McNemar’s test for paired proportions.

Finally, question 13 asked students to rate on a scale from 1 (strongly disagree) to 3 (neutral) to 5 (strongly agree) their agreement with the statement: “There is more macro-diversity contained on the branches of a tree (e.g. pine tree) than there is non-bacterial micro-diversity on or in the soil below that tree.” I evaluated the percentages of students with answers scored as ‘correct’—those who answered 1 or 2—before and after completing both the traditional and new biodiversity exercises. I found that the proportions of correct answers pre- and post-exercise were the same within each group. Students who completed the traditional biodiversity exercise remained at 43.4% correct (McNemar’s test for paired proportions, \( n = 46, p = 1.00 \)), and students who completed the new biodiversity exercise remained at 57.4% correct (McNemar’s test for paired proportions, \( n = 61, p = 1.00 \)).

Construct 2: Questions 47, 48, 49, 50, and 51

I checked internal reliability among this block of questions (47 through 50) to determine whether these questions measured the construct “student attitudes towards fieldwork effectiveness on their own learning” and report a Cronbach’s alpha of 0.823. 
Typically, a Cronbach’s alpha of 0.700 or higher reveals high internal reliability (Gliem & Gliem, 2003; Lovelace & Brickman, 2013). Wilcoxon signed-rank tests showed that students who completed the new biodiversity exercise exhibited significant changes in their ratings of agreement on question 48 ($Z = -3.77$, $p < 0.001$, $r = -0.339$), question 49 ($Z = -2.57$, $p = 0.010$, $r = -0.231$), and question 50 ($Z = -2.43$, $p = 0.015$, $r = -0.218$) and a non-significant change on question 47 ($Z = -0.83$, $p = 0.409$). Wilcoxon signed-rank tests showed that students who completed the traditional biodiversity exercise exhibited non-significant changes in their ratings of agreement on question 47 ($Z = -0.38$, $p = 0.707$), question 48 ($Z = -0.64$, $p = 0.520$), question 49 ($Z = -0.46$, $p = 0.643$), and question 50 ($Z = -0.37$, $p = 0.712$). I illustrate the changes in mean ratings for all Likert-type questions (Figure 2.7) and show pre-post trends for questions 48 through 50 (Appendix Figures A.1-A.3).

Additionally, I found that 64.5% (40 out of 62) of the students who completed the new biodiversity exercise indicated on question 51 that they felt it allowed them to better notice and recognize biodiversity around them (Figure 2.8). While this question was included on the post-exercise survey given to all students in the study, those who did not complete the new biodiversity exercise selected the answer “non-applicable”.

**Construct 3: Questions 14, 16, 26, 28, 30, 31, 33, and 39**

I found no significant difference between the students who completed the traditional biodiversity exercise and the new biodiversity exercise with regard to their abilities to make real world connections to their study of biology. In addition to the
analyses described below, I also present the relevant data with parametric analyses (Appendix Table A.3).

A Wilcoxon signed-rank test showed that students who completed the new biodiversity exercise significantly shifted their rating of agreement with question 14 (Z = -6.37, p < 0.001, r = -0.572), whereas students who completed the traditional biodiversity exercise did not significantly shift their rating of agreement with question 14 (Z = -0.63, p = 0.527). I illustrate the changes in mean ratings for question 14 (Figure 2.9) and show pre-post trends (Appendix Figure A.4).

For question 33 (Figure 2.9)—part of the “real world connections” cluster from (Semsar et al., 2011)—I found that only students who completed the traditional biodiversity exercise significantly shifted their rating of agreement (Wilcoxon signed-rank test, Z = -2.076, p = 0.038, r = -0.216). While this one question suggested a shift towards a more expert-like ability to make connections between the study of biology and the “real world,” I did not find an overall trend for either group of students. I illustrate the changes in mean ratings for question 33 (Figure 2.9) and show pre-post trends (Appendix Figure A.5).

Discussion

My results indicate that students who completed my new field- and inquiry-based biodiversity exercise demonstrated an increased understanding and awareness of ground-dwelling invertebrate biodiversity upon completion of the exercise. After completing the exercise, students named more ground-dwelling invertebrates (question 10) and recognized that Earth’s multicellular animal biodiversity consists of more than just
chordate diversity (question 12). But, relative to the traditional exercise which also increased student understanding and awareness of ground-dwelling invertebrate biodiversity, my new exercise produced greater mean gain in number of ground-dwelling invertebrates named (question 10).

Interestingly, neither group exhibited changes in the proportions of ‘correct’ answers provided on question 13 after completing either exercise. Fewer than half (43.4%) of the students who completed the traditional biodiversity exercise supplied correct responses before and after completion of the traditional exercise, and more than half (57.3%) of the students who completed the new biodiversity exercise supplied a correct response before and after completion of the new exercise. Nonetheless, neither exercise produced a negative change in correct answers, as the percent correct remained the same within each group.

I found that my new biodiversity exercise produced a significant shift in student agreement with the benefits of fieldwork and hands-on activities with regard to their learning and understanding of biodiversity. For Likert-questions 48, 49, and 50, I noted significantly higher student agreement with the ideas a) that they are able to better understand biodiversity through fieldwork activities than through simple lecture-based activities and b) that collection of their own specimens allowed for better understanding of biodiversity among students who completed my new biodiversity exercise. I found it interesting that while the students who completed the traditional exercise typically agreed with these ideas about fieldwork before the exercise, they showed no significantly positive shift in agreement afterwards. I do not find that surprising, however, given that
those students had a shortened field exercise and received pre-collected specimens in addition to those that they collected.

With respect to student ability to make connections between their biology coursework and the real world, I found no overall pre- and post-exercise differences for students who completed the traditional biodiversity exercise or my new biodiversity exercise. I used question 14 in conjunction with the CLASS-Bio “Real World Connections” (Semsar et al., 2011) cluster of questions to measure this ability. After completion of my new biodiversity exercise, students strongly felt that they do have many interactions with biodiversity in their daily lives (question 14). Before completion of my new exercise, 40 of 62 students (64.5%) selected either “agree” or “strongly agree” with that statement (i.e., meaning that students largely agreed that they did not have many interactions with biodiversity in their daily lives). After completion of my new exercise, 53 of 62 (85.5%) students selected either “strongly disagree” or “disagree” with that statement indicating that they no longer felt they lacked interaction with biodiversity in their daily lives. However, this was not the case for students who completed the traditional exercise, as 31 of 46 (67.8%) of them selected either “strongly disagree” or “disagree” before completion of the traditional biodiversity exercise. After completion of the traditional exercise, 35 of 46 (76.1%) students selected either “strongly disagree” or “disagree” for question 14. While the percentage of students who disagreed with that statement did increase upon completion of the traditional exercise, it was not a statistically significant increase.

While question 33 did reveal a shift to more expert-like views concerning student abilities to make connections between the real world and their biology classes in the
students who completed the traditional exercise, I found no significant overall trend in this characteristic. Therefore, I am unable to conclude that by completing my new exercise or the traditional biodiversity exercise, student thinking would shift to more expert-like views. I also do not find this surprising, as student perceptions often shift to more novice-like views over a semester of instruction in an introductory biology class (Semsar et al., 2011).

When taken together, the results of the objective questions do not suggest a decisive difference between the students who completed my new biodiversity exercise and those who completed the traditional exercise. Nonetheless, I propose that those results taken in conjunction with those of the Likert-type questions (14, 48, 49, 50, and 51) demonstrate that my new exercise has a more positive impact on student learning than the traditional exercise. I suggest that further studies should be undertaken with new or additional objective questions to provide a broader scope.

I decided to center this study on the topic of invertebrate biodiversity education because that diversity is easily accessible in urban environments. Some students have successfully examined urban soil ecology (Johnson & Catley, 2009) and plant-arthropod interactions (Richardson & Hari, 2008) in local environments. For educators to implement an exercise such as mine, its benefits must outweigh any perceived difficulties of implementation.

I should also note that a limitation to this study is the low response rate of students to the pre- and post-surveys. My response rate was 37.8% of the enrolled students in Biology 1101. A lower response rate can indicate a nonresponse error or bias
because those who have responded to a survey may have something inherently different about them than those who did not respond (Draugalis & Plaza, 2009).

I suggest that my response rate may be lower because my primary reminders to research participants about survey completion were delivered by email with posts on the course management system as secondary reminders. Other researchers have found that when reminding research participants to complete surveys, email only modes can lead to lower response rates (Fincham, 2008; Yun & Trumbo, 2000). However, because this was a large introductory course, the only feasible way in which to communicate effectively with students was through their student email and the course management system.

**Limitations to exercise implementation**

Limitations to the implementation of inquiry-based exercises may exist. Mandated curricula (Donnelly, O’Reilly, & McGarr, 2012) and teacher doubts about feasibly implementing different methodologies—such as inquiry-based methods (Cheung, 2011)—appear to limit the number of inquiry-based activities incorporated into biology courses. Additionally, full “field trips”—those in which students ride a bus to a field site, zoo, or botanical garden—can be costly and impractical (Johnson & Catley, 2009; McCoy, McCoy, & Levey, 2004). My field exercise, requiring inexpensive materials and negligible travel, could be a viable alternative to such “field trip” activities.

**Conclusion**

My results support the hypothesis that students who complete an inquiry-based field biodiversity exercise will have a better understanding and awareness of ground-
dwelling invertebrate biodiversity and more positive attitudes towards fieldwork and hands-on activities than will students who complete a traditional biodiversity exercise lacking extensive inquiry- and fieldwork-based components. Indeed, students have reported finding greater value in sampling and categorizing biodiversity than in receiving pre-collected specimens (Scott et al., 2011). While a traditional biodiversity exercise—such as OSU’s traditional biodiversity exercise—may confer some benefits to students, I suggest that exercises with a clear inquiry-based approach and a larger fieldwork component—such as my new exercise—facilitate better learning outcomes. Even though I designed my exercise for an introductory biology course, educators can easily adapt and modify the duration and topic coverage of the exercise depending on the student audience. My work adds to literature reporting the advantages of inquiry-based pedagogical methods in achieving learning goals in science education (Davis-Berg, 2011; Goldey et al., 2012; Rissing & Cogan, 2009; Spiro & Knisely, 2007; Timmerman et al., 2008) and in raising student confidence in the benefits of fieldwork activities (Boyle et al., 2007; Dunphy & Spellman, 2009; Scott et al., 2011; Tessier, 2004).

Given the arrival of a sixth mass extinction event (Barnosky et al., 2011) and growing student dissociation from nature (Awasthy et al., 2012; Johnson & Catley, 2009), educators who expect to raise student concern about global biodiversity issues must find simple and effective ways for students to connect with biodiversity. Inquiry-based exercises like my new biodiversity exercise can be more effective than traditional classroom activities in increasing student understanding and recognition of biodiversity and in reshaping student attitudes towards the benefits of fieldwork. Most importantly, by
simply having students experience the biodiversity around them, biology educators can
begin to help students understand and ask more questions about the natural world.
Table 2.1 Comparison of the traditional and new biodiversity exercises for BIO 1101: Introductory Biology for non-majors. I provide complete student and instructor versions of the new biodiversity exercise in Appendices C and D.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Traditional</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of biodiversity focus</td>
<td>Broad animal and plant taxa</td>
<td>Arthropods and other ground-dwelling invertebrates</td>
</tr>
<tr>
<td>Student collection of organism(s)/substrate(s)?</td>
<td>Some/No</td>
<td>Yes/Yes</td>
</tr>
<tr>
<td>Use of pre-collected organism(s)?</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Study of natural history (by sketching organism(s) collected and observed)?</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Student recording of field notes?</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Discussion of history of taxonomic work (people and methodologies)?</td>
<td>Briefly in lab introduction: “many [questions about species relationships] were raised by Aristotle...”</td>
<td>Specific mentioning of Antonio Berlese and his work discovering relationships between soil invertebrates</td>
</tr>
<tr>
<td>Guiding questions to help distinguish differences between specimens collected?</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>“Just-in-time” background information given?</td>
<td>No</td>
<td>General statistics about arthropod diversity</td>
</tr>
<tr>
<td>Student discussion of linkage of organism(s) collected to environment(s) from which it was collected?</td>
<td>No</td>
<td>Yes: “How did your sample differ in terms of results (i.e., what you found and how much) and collection substrate details (e.g., leaf duff versus pine cones) from a lab group with a different substrate type?”</td>
</tr>
<tr>
<td>Practice with usage of simple pictorial keys to ID specimen(s)?</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Wrap-up discussion of commonly found organism(s)?</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Separate instructor guide?</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Figure 2.1. A Berlese funnel apparatus as modified and used by students. Students placed collected substrates into a modified two-liter plastic bottle (C). Light from a standard gooseneck lamp (D) with an incandescent bulb drove small invertebrates through wire mesh (B) placed inside the bottle. Once invertebrates passed through the mesh, they fell into a Styrofoam cup (A) containing a 70% ethanol solution.

Figure 2.2. Top view of a Berlese funnel apparatus. Substrates rested on wire mesh (B) inside of a modified two-liter plastic bottle (A). Invertebrates fell through the opening of the bottle (C) and into a Styrofoam cup containing a 70% ethanol solution.
Table 2.2. Constructs tested by pre-post assessments in both control (traditional biodiversity exercise) and treatment (new biodiversity exercise) lab sections of BIO 1101: Introductory Biology for Non-Majors. I provide the full list of assessment questions in Appendix B.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Number of questions</th>
<th>Source of questions</th>
<th>Question cluster</th>
<th>Type of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding and recognition of relative abundance of arthropods (and other soil/ground-dwelling invertebrates)</td>
<td>4</td>
<td>All original to study except question 10 “List 5 different animal species…” adapted from White (2009)</td>
<td>10, 11, 12, 13</td>
<td>Numerical/Ordinal</td>
</tr>
<tr>
<td>Student attitudes towards efficacy of fieldwork aspect(s) incorporated in classes with regard to their learning success</td>
<td>4 (5 questions on post-survey for treatment section only)</td>
<td>Original to study</td>
<td>47, 48, 49, 50, (51)</td>
<td>Ordinal</td>
</tr>
<tr>
<td>Student perceptions of real world connections with biology</td>
<td>8</td>
<td>One original to study (question 14), plus CLASS-Bio instrument “real world connections” question cluster: original questions numbering 2, 12, 14, 16, 17, 19, 25 (Semsar et. al., 2011)</td>
<td>14, 16, 26, 28, 30, 31, 33, 39</td>
<td>Ordinal</td>
</tr>
</tbody>
</table>

Table 2.3. Example of coding process for an anonymous student’s response to pre-post assessment question 10: “List 5 different animal species (common names are acceptable) that you can expect to find around OSU’s campus. As an example to help you understand the format: instead of writing ‘mammal’, write ‘red kangaroo’ or ‘Macropus rufus’.”

<table>
<thead>
<tr>
<th>Original pre-exercise response</th>
<th>Coded response</th>
<th>Percent soil invertebrate*</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Birds”</td>
<td>Vertebrate</td>
<td>3/5 responses; 60 % soil invertebrate responses</td>
</tr>
<tr>
<td>“Squirrel”</td>
<td>Vertebrate</td>
<td></td>
</tr>
<tr>
<td>“Beetles”</td>
<td>Soil Invertebrate</td>
<td></td>
</tr>
<tr>
<td>“Worms”</td>
<td>Soil Invertebrate</td>
<td></td>
</tr>
<tr>
<td>“Ants”</td>
<td>Soil Invertebrate</td>
<td></td>
</tr>
</tbody>
</table>

*Where soil invertebrate indicates specimen discoverable with a Berlese funnel apparatus as used and described in this study
Table 2.4. Examples of coding process for student responses to pre-post assessment question 11: “What kinds of locations on OSU’s campus might you expect to find the most animal diversity? (List 3 locales and describe briefly—less than 5 words—why you believe each is a good locale for that diversity.)”

<table>
<thead>
<tr>
<th>Original response</th>
<th>Coded response</th>
<th>Percent arthropod locale</th>
</tr>
</thead>
<tbody>
<tr>
<td>“In the ground – lots of small bugs”</td>
<td>Arthropod locale (ART)</td>
<td>1/3 responses; 33.3% arthropod locale responses</td>
</tr>
<tr>
<td>“In the river – lots of fish and underwater creatures”</td>
<td>Non-arthropod locale (NART)</td>
<td></td>
</tr>
<tr>
<td>“In the trees – lots of birds and squirrels”</td>
<td>Non-arthropod locale (NART)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.5. Examples of coding process for student response to pre-post assessment question number 12: “Which group(s) of animal do you think are most abundant (i.e., greatest number of animal species per group in many of the world’s ecosystems)?” I coded original responses into six categories and then marked them as correct or incorrect.

<table>
<thead>
<tr>
<th>Original response</th>
<th>Coded response</th>
<th>Correct/incorrect</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Humans”</td>
<td>Human (HU)</td>
<td>Incorrect</td>
</tr>
<tr>
<td>“Birds”, “Mammals”, etc.</td>
<td>Non-Human Vertebrate (NHV)</td>
<td>Incorrect</td>
</tr>
<tr>
<td>“Earthworms”, “Nematodes”, etc.</td>
<td>Non-Arthropod Invertebrate (NAI)</td>
<td>Incorrect</td>
</tr>
<tr>
<td>“Bacteria”, “Plants”, etc.</td>
<td>Other (O)</td>
<td>Incorrect</td>
</tr>
<tr>
<td>“Beetles”, “Insects”, etc.</td>
<td>Insect (INS)</td>
<td>Correct</td>
</tr>
<tr>
<td>“Arthropods”</td>
<td>Arthropod (ART)</td>
<td>Correct</td>
</tr>
</tbody>
</table>

Table 2.6. Coding process for student responses to pre-post assessment question 13: “There is more macro-diversity contained on the branches of a tree (e.g. pine tree) than there is non-bacterial micro-diversity on or in the soil below that tree.” Students responded on a scale from 1 (strongly disagree) to 5 (strongly agree).

<table>
<thead>
<tr>
<th>Original response</th>
<th>Correct/incorrect</th>
</tr>
</thead>
<tbody>
<tr>
<td>3, 4, or 5</td>
<td>Incorrect</td>
</tr>
<tr>
<td>1 or 2</td>
<td>Correct</td>
</tr>
</tbody>
</table>
Figure 2.3. Mean numbers of ground-dwelling invertebrates named (presented with 95% confidence intervals) on survey question 10 by students in BIO 1101: Introductory Biology for Non-Majors before and after completing the traditional (control) or new (treatment) biodiversity exercise.
Figure 2.4. Frequency of student answers to survey question 10 by students in Bio 1101: Introductory Biology for Non-Majors before and after completing the traditional (control) or new (treatment) exercise.

Each student could provide up to 5 animal species for question 10. Numbers on the horizontal axis indicate the number of soil invertebrates mentioned out of a possible five.
Figure 2.5. Gains in mean numbers of ground-dwelling invertebrates named (presented with 95% confidence intervals) on question 10 by students in BIO 1101: Introductory Biology for Non-Majors after completing the traditional (control) or new (treatment) biodiversity exercise. (Independent T-test, $t_{94.187} = 2.07, p = 0.041$)
Figure 2.6. Percentages of BIO 1101: Introductory Biology for Non-Majors students’ answers coded as either ‘Arthropod’ or ‘Insect’—scored as correct—for question 12 before and after completing the traditional or new biodiversity exercise.

a = significant for traditional exercise; b = significant for new exercise

Figure 2.7. Changes in mean ratings on indicated Likert-type questions concerning student attitudes towards fieldwork effectiveness on their learning from students in BIO 1101: Introductory Biology for Non-Majors before and after completing the traditional or new biodiversity exercise.

Note: The max possible rating is 5—strongly agree—however, the graph has been extended to 6 to illustrate fully the standard deviations for some of the statements.
Figure 2.8. BIO 1101: Introductory Biology for Non-Majors student responses to question 51: "After completing the Berlese funnel exercise, I feel that I can better notice and recognize the biodiversity around me."

Figure 2.9. Changes in mean answers to Likert-type question 14 measuring student perceptions of interactions with biodiversity and to Likert-type question 33* measuring student perceptions of their real world connections to biology from students in BIO 1101: Introductory Biology for Non-Majors before and after completing the traditional or new biodiversity exercise.

*Question 19 on CLASS-Bio Survey (Semsar et al., 20
Chapter 3: Evaluation of Apple iPads in and out of the Biology classroom

Introduction

Inquiry-based learning, where students achieve learning outcomes through self-motivated investigation, is well-supported as a pedagogical method that facilitates student learning gains when compared to traditional, didactic approaches (Lord & Orkwiszewski, 2006; Luckie et al., 2012; Rissing & Cogan, 2009). These teaching techniques demand trained facilitators to guide inquiry and require that students use the appropriate techniques to gather and share information. Incorporating new technologies into the classroom for gathering and sharing of information has increased considerably with technological development in the 21st century, including inquiry-based learning. Recently, tablet PCs, iPads®, and other mobile technologies have become the focus of many curricula across the United States. For example, tablet PCs have been used in undergraduate mathematics courses to facilitate problem solving amongst students (Romney, 2009) and iPads have been used as replacements for traditional pen and paper lab notebooks in chemistry labs (Hesser & Schwartz, 2013).

While the implementation of mobile technologies has continued to increase, empirical investigations on their effectiveness in enhancing the education experience remain few. An iPad-based laboratory manual in an anatomy class helped students stay “on-task” and increased student perceptions of achievement of learning objectives,
engagement, and the overall dissection experience (Mayfield, Ohara, & O’Sullivan, 2013) while higher class attendance rates were achieved by students using iPads in a sports medicine anatomy class compared to students who completed the class without iPads (Wilkinson & Barter, 2015). Other studies have shown that these classroom tools can improve student motivation and increase student value of the course (Gong & Wallace, 2012), increase retention rates (Romney, 2011), and increase student perceptions of learning and engagement (George et al., 2013; Rossing, Miller, Cecil, & Stamper, 2012). While previous work suggests that students value and respond positively to the use of mobile technology, no current research has provided empirical evidence that the replacement of traditional classroom activities with those that utilize mobile technologies, such as iPads, increase learning gains for students. Additionally, because no studies exist on the evaluation of iPads used as replacements for lab notebooks and its effect on student learning gains, we chose to evaluate iPads as digital field and lab notebooks.

I compare learning gains between two biology classes in which either iPads or traditional classroom tools were used as digital field notebooks and digital sharing devices. I examined the raw student data from this comparison to answer the following questions:

1) Will students readily use iPads if they are provided as a learning tool?

2) Does familiarity with the functioning of iPads affect student ability to use iPads effectively?

3) Does the use of iPads for gathering and sharing field and/or laboratory data affect student-learning outcomes?
I hypothesized that if students were provided iPads as a learning tool, they would readily use them. I hypothesized that those students who were more familiar with the operation of iPads and Apple computers would gather more data with the iPads than students who were less familiar with the operation of iPads and Apple computers. I also hypothesized that if students used iPads for gathering and sharing field and or laboratory data, they would record more raw data (defined as numbers of pictures and words recorded) than students who used traditional pencil-and-paper field notebooks, and would subsequently score higher on related summative assessments.

Materials & Methods

Course Context

I examined student products from two studio-based biology courses that were actively expanding iPads into their curricula: Ohio Plants (EEOB 2210) and Organismal Diversity (EEOB 3320) in the Department of Evolution, Ecology, and Organismal Diversity at The Ohio State University. This study occurred in parallel across both classes for four terms: Autumn 2014, Spring 2015, May 2015, and Autumn 2015.

In both studio-based courses, instructors utilized active-learning, student-centered pedagogical methods that often involved the dissection or observation of specimens. Ohio Plants served as an elective for students majoring in biological sciences with a class capacity of approximately 32 students while Organismal Diversity served as core course for Zoology majors and an elective for students majoring in biological sciences, with a class capacity of approximately 52 students. Participation rates of students ranged from 80-100% (Table 3.1).
Technology Specifications

During the treatment sections of Ohio Plants and Organismal Diversity, each student received one 4th generation 16 GB Apple iPad and Otterbox case to use for the duration of the term. Each iPad was loaded with the latest iOS and the applications (apps), Box and Notability. Students extensively used both apps in order to take notes and pictures of coursework (Notability app) and submit classroom assignments (Box app). For all students in the treatment sections of either course, instructors brought in representatives from the College of Arts and Sciences Technology Services department to provide basic tutorials on iPad usage (e.g. setting up Apple IDs and iCloud, email, introduction to the Box and Notability applications).

In the Organismal Diversity studio, students utilized the AirPlay function on the iPads in order to share pictures and notes of their organism dissections. The Organismal Diversity studio classroom has four, 60” flat screen LCD televisions [screen] placed around the room to facilitate projection and sharing of student work.

Pre-Post Technology Surveys

In order to evaluate the familiarity of students with mobile technology, I developed a technology survey specific to the use of iPads in the classroom (Appendix G). To encourage participation in the surveys, I offered an incentive of 2.5 bonus points per survey attempt (for a total of 5 points to complete both the pre- and post-technology survey). I administered each survey for seven days during the first and last week of each course through the online survey tool, SurveyMonkey.
I piloted my initial technology survey during the Autumn 2014 semester. During subsequent semesters, we added additional questions to specifically address student attitudes towards particular iPad usages and perceived benefits (see final survey, Appendix G). I only administered the pre-technology survey to the control group classes in both courses because student attitudes towards technology were expected not to change in absence of a technology treatment.

I used answers to a subset of the questions from the surveys as predictors of iPad use (questions 10 through 12 for both Ohio Plants and Organismal Diversity; question 13 only used for Organismal Diversity) (Table 3.2). For example, I hypothesized that if a student was more familiar with Apple computers or iPads, they would gather more raw data with the iPad. When a student consented to the study but did not complete the pre- or post-technology survey, they were removed from comparisons of how predictors of iPad use related to the acquisition of raw data.

At the end of the technology survey, I asked students to “elaborate on things you liked about using iPads in the classroom/field” and to “elaborate on things you did not like about using iPads in the classroom/field”. In order to refine student answers, I revised the question for all subsequent semesters so that students would specify three things that they liked and three things that they would change about iPad usage.

*iPads as Digital Field Notebooks*

I focused data collection on a specific field activity that I modified for use in both Ohio Plants and Organismal Diversity, the Gymnosperm exercise (Appendix H and I). This outdoor lab takes place at OSU’s Chadwick Arboretum and allows students to
observe directly and form hypotheses on the evolution and diversity of reproduction in seed-producing plants using guided-inquiry pedagogical methodology. Student groups were assigned to a specific set of Gymnosperms and asked to document their observations of the specific features of these plants. During the time in which students explored assigned specimens, instructors walked around the arboretum in order to ask students guiding questions to ensure that they focused on diagnostic traits of those specimens. Students then engaged another group that had analyzed the same group of plants and compared their conclusions concerning the reproductive structures. Finally, groups shared their findings and compared/contrasted their conclusions with other groups by giving a short presentation to all other students. At the end of the class, groups submitted their notes, which were evaluated by assigning points for the completeness of drawings/photos, labeling of structures, and written observations. This activity occurred approximately halfway through the semester. In order to ensure that students took adequate notes during the exercise, during the term their notes were evaluated weekly to encourage thorough note-taking and synthesis of course content.

In order to determine my hypothesis that if students gathered more data, then they would subsequently score higher on quiz questions specific to the learning objectives of the Gymnosperm exercise, I evaluated the number of words and pictures that the students took when completing the exercise. This evaluation was conducted for both classes (Ohio Plants and Organismal Diversity) for both students who used iPads as digital field notebooks and those who used traditional pencil-and-paper field notebooks. Quiz questions and learning objectives differed between the two courses, but remained consistent for within each course across the duration of the study.
**iPads as Digital Sharing Devices**

To evaluate if the use of iPads within the studio classroom facilitated greater sharing of content, I collected student raw data and associated assessments from six units of instruction (early chordates, nematodes, arthropods, ground-dwelling soil invertebrates, mollusks, and general invertebrate wrap-up). I evaluated this content within three sections of Organismal Diversity (two sections in Spring 2015, one section in Autumn 2015). Each week, instructors presented a different group of organisms (e.g., arthropods) to the students. Organismal Diversity utilized guided-inquiry approaches where students explored specimens that represented the group of organisms examined that week. Students took detailed notes to reflect their explorative dissections and were challenged to provide linkages between the physiological structures they observed and the evolution and ecology of the organism. Studio time was often interspersed with short lectures that provided background or guidance for features that the students may not be able to directly observe on their specimens. Due to variation between specimens and different group members dissecting different specimens, the sharing of information between students within the class was imperative to student success. Students could instantly share their iPad content with all of the other students in the room via Apple Airplay on the television screens, including the addition of annotations or highlights. For example, if a group of students was dissecting the only female sea lamprey in the studio, they could take a photo of the reproductive structures, highlight what they hypothesized were lamprey ovaries, and display their photo across all of the studio televisions.

Students used this sharing technology as a supplement to their notebook observations by...
using the observations of other student to compare/contrast with the male lamprey reproductive structures observed in their own dissection of a male specimen.

In order to determine if students gathered more data, shared more information, and subsequently performed better on quizzes relating to the learning objectives of a given “instructional unit”, I evaluated the number of words, pictures, and instances of sharing that the students reported in their notebook submission for the week. I did this evaluation for students who used iPads as sharing devices and those students who only utilized traditional pencil-and-paper field notebooks and compared the results. Sharing between students is a complex behavior and difficult to quantify, so I identified two types of sharing of dissection observations and explorations that could be reliably self-reported by students: 1) They utilized Apple Airplay to project pictures and annotations, or 2) They walked to adjacent tables and shared information in a “traditional” way. For students in the control group, they only had the capability to share information in the traditional way. Additionally, to ensure that students shared information in some capacity in both the treatment and control classes, I asked students to “share their findings with at least one other group” on the instructional PowerPoint slides for the activities of each unit. Whenever students shared information in either format, I asked that they indicate the source of their information (i.e., from which table did they acquire the observation or sketch) on the instructional PowerPoint slides and the associated notebook rubric for the week. Each week students submitted their notebooks electronically for evaluation.

Using the above procedures, I collected the total amount of raw data recorded by students (words and pictures) during their investigations as well as the percentage of this raw data associated with two peer sharing mechanisms. As a response parameter that
represents student achievement of learning outcomes, I collected the scores from quiz questions that related to the learning objectives of a given “instructional unit” and compared the results between those students who used iPads to record/share information and those who used only traditional pencil-and-paper field notebooks. We summarized the student data that we collected and evaluated for treatment and control groups in Organismal Diversity.

The Behavioral and Social Sciences IRB in The Office of Responsible Research Practices at The Ohio State University approved my protocol for the evaluation of iPads in the biology classes Ohio Plants and Organismal Diversity (for this study) for expedited review (Protocol Number: 2014B0090). All participating subjects were 18 years of age or older.

Data Analysis

I performed one-way ANOVA (Ramsey & Schafer, 2013) to determine any differences in the following parameters between the control (iPads absent) and treatment classes (iPads present):

- mean word count, picture count, and summative scores for the Gymnosperm exercise (for both Ohio Plants and Organismal Diversity)
- mean word count, picture count, and summative scores for three instructional units: Ground-Dwelling Invertebrates, Mollusks, and Arthropods (Organismal Diversity only)
• total words shared, total pictures shared, and total tables visited for three instructional units: Ground-Dwelling Invertebrates, Mollusks, and Arthropods (Organismal Diversity only)

If the one-way ANOVA was significant, a Fischer’s Least Significant Difference (LSD) post-hoc test was used to determine differences among means.

I performed multiple regression analyses (Ramsey & Schafer, 2013) to determine:

• if numbers of words or sketches/pictures predicted performance on summative assessments for the Gymnosperm exercise in either Ohio Plants and Organismal Diversity.

• if total shared words (traditionally shared + screen shared), total shared pictures (traditionally shared + screen shared), and total table visits (traditional + screen) predicted performance on summative assessments.

Before I performed regression analysis for total shared words, total shared pictures, and total table visits in Organismal Diversity, I removed any students who had zero table visits recorded. I did this because we cannot say with confidence that these students did not share findings; they simply may have failed to report their sharing of information with classmates despite various prompts and instructions for doing so.

Additionally, I ran two and three-way ANOVA (Ramsey & Schafer, 2013) to determine if:

• student responses to pre-technology survey questions 9 through 12 had predicted word count, picture count, and summative scores for the Gymnosperm exercise in either Ohio Plants or Organismal Diversity
• student responses to pre-technology survey questions 9 through 11 and question 13 predicted shared words, shared pictures, and tables visited for six units of instruction in Organismal Diversity during the classes in which iPads were utilized for sharing.

For the pre- and post-technology surveys, I performed nonparametric Wilcoxon signed-rank analyses on my Likert survey data because these data do not follow a normal distribution (Lovelace & Brickman, 2013; Ramsey & Schafer, 2013). With the Wilcoxon signed-rank tests, I tested the null hypotheses that the population mean ranks did not differ before and after one full semester of use with the iPads in either Ohio Plants or in Organismal Diversity. Additionally, I report the effect size, r, as given by the following equation:

\[ r = \frac{Z \text{ score}}{\sqrt{N}} \]

For Wilcoxon signed-rank tests, N equals the sample size multiplied by two. For Mann-Whitney U tests, N equals the sample sizes of the two groups added together (Field, 2005). For effect sizes, we reported 0.1 as small, 0.3 as medium, and 0.5 as large (Cohen, 1988).

In order to uncover emergent themes from student responses (Seidman, 1998), I used all of the free responses from the post-technology surveys in both classes. I developed consensus agreement with another researcher on emergent themes found in student free response answers to the post-technology survey questions in order to have consistency with categorization of those answers.
Results

*iPads as Digital Field Notebooks*

Gymnosperm Exercise: Ohio Plants

No significant differences were evident between the number of words or number of pictures recorded between groups that used iPads and those that used pencil and paper. However, there was a statistically significant difference between summative scores (one-way ANOVA, $F_{(2,70)} = 7.991$, $p = 0.001$; Figures 3.1-3.3, Table 3.3).

Summative scores during Autumn 2014 (iPads present; 78.6% ± 13.5%) were significantly lower than both the summative scores during Autumn 2015 (iPads absent) (85.1% ± 9.0%, $p = 0.042$; Fisher’s LSD post-hoc test) and May 2015 (iPads present) (92.5% ± 11.8%, $p < 0.001$). Additionally, I found that the summative scores from May 2015 (iPads present) were significantly higher than the summative scores from Autumn 2015 (85.1% ± 9.0%, $p = 0.028$).

The number of words written or recorded and the number of pictures sketched or taken did not predict the summative score earned by students on quiz questions relating to the learning objectives of the Gymnosperm exercise ($F_{(2,70)} = 0.649$, $p = 0.525$, $R^2 = 0.018$).

No significant interaction was observed between student ratings on their comfort with iPads, comfort with Apple computers, or ratings on iPad usage as a digital laboratory notebook on words recorded with iPads or pictures taken with iPads by students on the Gymnosperm Exercise. However, interactions were evident between
student ratings on their comfort levels with Apple computers (two-way ANOVA, $F_{(1,24)} = 6.093$, $p = 0.036$) and on their ratings on iPad usage as a digital laboratory notebook (two-way ANOVA, $F_{(3,24)} = 4.978$, $p = 0.026$) on summative scores relating to the learning objectives for the Gymnosperm exercise. Students who identified as very comfortable with Apple computers (score of 3) scored significantly lower on the Gymnosperm exercise summative assessments than those students who identified as somewhat comfortable with Apple computers (score of 2) by a mean difference of 13.6 percentage points (Fischer’s LSD post-hoc test; $p = .010$; Figure 3.4). Students who disagreed that iPads used as a digital laboratory notebook would be beneficial to their learning (rating 2) performed significantly lower on the Gymnosperm summative assessments than those who were neutral (mean difference = 24.8 %, $p = 0.003$), agreed (mean difference = 16.5%, $p = 0.023$), or strongly agreed (mean difference = 18.8%, $p = 0.012$; Figure 3.5).

In order to demonstrate the capabilities of the iPads when used as digital field notebooks in comparison to traditional pencil-and-paper notebooks, I have provided sample student work (Appendices J and K). In the sample work, I have provided a completed version of the Ohio Plants Gymnosperm exercise from Autumn 2015 using a traditional pencil-and-paper notebook (Appendix J) and from Autumn 2014 using iPads and the app, Notability (Appendix K).
Gymnosperm exercise: Organismal Diversity

No significant differences were found between the number of words, number of pictures recorded, summative scores by students completing the exercise with either iPads as their digital field notebooks or traditional pencil-and-paper field notebooks in Organismal Diversity (Figures 3.6-3.8).

The number of words written or recorded and the pictures sketched or taken did not predict the summative score earned by students on quiz questions relating to the learning objectives of the Gymnosperm exercise ($F_{(2, 67)} = 2.184$, $p = 0.121$, $R^2 = 0.061$).

No significant interaction was observed between student ratings on their comfort with iPads, comfort with Apple computers, or ratings on iPad usage as a digital laboratory notebook on words recorded with iPads or pictures taken with iPads by students in Organismal Diversity on the Gymnosperm exercise (Table 3.4).

**iPads as Digital Sharing Devices**

Regression analysis revealed that total shared words (traditionally shared + screen shared), total shared pictures (traditionally shared + screen shared), and total table visits (traditional + screen) did not predict summative scores for all six units ($F_{(3, 91)} = 0.910$, $p = 0.439$, $R^2 = 0.029$).

After performing the regression analysis, three units were analyzed and presented three units in depth: Arthropods, Ground-Dwelling Soil Invertebrates, and Mollusks. These units were chosen because 1) students had additional weeks to familiarize with one another and the technology, which in turn, may promote more sharing, and 2) the ground-
dwelling soil invertebrate unit was particularly more conducive to sharing because students utilized the skills with dissection and identifying specimens that they had honed throughout the semester.

No difference in the total words, total pictures, or summative scores was observed for either the ground-dwelling invertebrate unit or the mollusk unit when the control (pencil and paper) and treatment (iPads) groups were compared. However, a significant difference between total words recorded was observed during the arthropod unit (one-way ANOVA, $F_{(2, 73)} = 11.049, p < 0.001$; Figure 3.9).

I found that students in the Autumn 2015 section (iPads present) of Organismal Diversity recorded 204.7 ±44.8 more words than students in the Spring 2015 PM section (iPads present) (Fischer’s LSD post-hoc test, $p < 0.001$) and recorded 188.6 ±50.1 more words than students in the Spring 2015 AM section (iPads absent) ($p < 0.001$). No significant difference was observed between total pictures or summative scores received during the arthropod unit (Table 3.5).

For both the ground-dwelling invertebrate and mollusk units, no differences in total shared words, total shared pictures, or total table visits were observed between the three sections of Organismal Diversity. However, for the arthropod unit, total shared pictures differed between the three sections of Organismal Diversity (one-way ANOVA, $F_{(2, 30)} = 3.427, p = 0.046$). Students in the Spring 2015 AM section (no iPads present) shared 0.82 ±0.34 pictures more than students in Autumn 2015 section (iPads present) (Fisher’s LSD post-hoc, $p = 0.021$). No significant difference in total shared words or total table visits was observed for the arthropod unit (Table 3.6).
When comparing questions 9, 10, and 13 as predictors for total shared words, total shared pictures, and total tables visited across all units using a three-way ANOVA, no significant effects or interactions were observed for students who used iPads during Spring 2015 and Autumn 2015. The Spring 2015 section that did not use iPads for sharing was not included in this analysis as questions 9-13 should not be predictors for traditionally shared words.

*Comfort with Apple & iPads (Questions 9-11)*

In Ohio Plants, I tested the null hypothesis that student ratings on questions relating to their comfort with PC products, Apple computers, and iPads specifically would not differ before and after one semester of using iPads. The mean ratings pre-post did not differ significantly for questions 9 or 10 (Table 3.7) after the Autumn 2014 term of Ohio Plants (Wilcoxon signed rank test). However, the ratings of students did significantly change on question 11. Students felt more comfortable with iPads after a full term of use (Wilcoxon signed-rank test, \(Z = -2.520, \ p = 0.011, \ r = -0.4101\)). Student ratings on questions 9 through 11 did not differ after a term of iPad use during the May 2015 term of Ohio Plants, I accepted the null hypothesis (Table 3.7).

In Organismal Diversity, the mean ratings pre-post did not differ significantly for questions 9 or 10 (Table 3.8) after the Spring 2015 term of Organismal Diversity. However, for question 11, students felt more comfortable with iPads after a full term of use (Wilcoxon signed-rank test, \(Z = -2.236, \ p = 0.025, \ r = -0.2499\)). Student ratings on questions 9 through 11 did not differ after a term of iPad use during the Autumn 2015 term of Organismal Diversity, we accepted the null hypothesis (Table 3.8).
Perceptions of benefits of iPads (Questions 12-18)

Questions 13, 15, 16, and 17 did not appear on the pre-post technology survey during the Autumn 2014 term of Ohio Plants. For questions 12 and 14 during Autumn 2014 term, students changed their response from agreement to disagreement about the benefits of iPads to their learning. After an entire semester of using iPads, students felt that iPads used as digital lab notebooks were not beneficial to their learning (Wilcoxon signed-rank test, $Z = -2.124$, $p = 0.034$, $r = -0.3445$) and that iPads did not help them to engage in course materials ($Z = -2.814$, $p = 0.005$, $r = -0.4565$). During the May 2015 term, students did not agree with the statement that iPads facilitate group work more easily ($Z = -1.992$, $p = 0.046$, $r = -0.4066$).

After the full semester of using iPads during the Spring 2015 term, students did not agree that iPads used as digital lab notebooks (Wilcoxon signed-rank test, $Z = -3.798$, $p < 0.001$, $r = -0.4246$) or used as sharing devices ($Z = -4.713$, $p < 0.001$, $r = -0.5272$) were beneficial to their learning. Students also disagreed that iPads helped them learn course content in novel ways ($Z = -3.538$, $p < 0.001$, $r = -0.3955$), organize course content easily ($Z = -3.600$, $p < 0.001$, $r = -0.4025$), or that iPads facilitate group work easily ($Z = -2.572$, $p = 0.010$, $r = -0.2876$). After the use of iPads for an entire semester during the Autumn 2015 term, students felt that iPads did increase engagement in course materials ($Z = -2.652$, $p = 0.008$, $r = -0.4688$).

Finally, comparing technology survey attitudes to student learning gains between the two terms Spring 2015 and Autumn 2015 (Table 3.11), mean gains differed significantly for question 12 (Mann Whitney U test, $Z = -2.883$, $p = 0.004$, $r = -0.3852$), question 13 ($Z = -2.383$, $p = 0.017$, $r = -0.3184$), question 14 ($Z = -2.294$, $p = 0.022$, $r = -
0.3065), question 16 ($Z = -2.786, p = 0.005$, $r = -0.3722$), and question 17 ($Z = -2.439, p = 0.015$, $r = -0.3259$) (Table 3.11).

Open-ended survey questions (Questions 20 & 21)

Six emergent themes were identified in student answers with respect to aspects that they liked about using the iPads: note-taking capability, ease of use, photo capability/quality, internet access, sharing capability, and organizational function. Any other answers that did not fall into the major six themes, were placed in the “other” category. Since each student was able to provide three answers to each open ended survey question, the percentage of total student answers was reported. For example, twelve students participated in the post-technology survey during Ohio Plants May 2015. Each of the twelve students provided three answers for a total of 36 responses to question 20. In order to present this graphically, the number of raw responses in a given emergent theme was divided by the total number of answers (i.e., 36) and then multiplied by 100. Thus, we reported the percentage of total student responses. This process was repeated for the Organismal Diversity students (Figure 3.12).

Thirteen themes were identified in student answers with respect to aspects that they would change and/or disliked about using the iPads: the iBook project, liability responsibility, interface difficulty (i.e., issues with typing), uploading issues (with the Box app), making the iPads mandatory, using different applications, using them more in the class, size and/or case issues, distraction (e.g. social media use), using them to share lecture slides, not using them at all, and changing nothing. Additionally, three themes were found exclusively to Organismal Diversity: “use iPads exclusively”, “increase
screen sharing”, and “allow for full photograph incorporation in weekly notebook submissions”. Lastly, if answers did not fall into one of the sixteen themes, they were placed in the “other” category. Again, each student was able to provide three aspects of the iPad usage that they liked, so the percentage of total student responses was reported (Figure 3.13).

Discussion

All aspects of my study revealed that the use of iPads does not affect student outcomes positively or negatively. Students using iPads as field notebooks and sharing devices did not document more raw data and there was no subsequent relationship with scores on summative assessments. This result is consistent across student familiarity and student perception of benefits of iPads.

I found that students will use provided iPads, but not readily. I observed a general pattern in which students initially felt that the iPads would be beneficial to their learning by agreeing with the statements on the technology survey. However, after completion of an entire term with access to iPads, students did not agree that iPads were beneficial to their learning (Tables 12 and 13). In addition, students revealed on the open-ended survey questions that while they liked certain things the iPads could do (e.g., taking high quality pictures and note-taking capabilities), they recognized that iPads should enhance the learning experience by utilizing them in ways that are more effective (e.g., sharing instructor lecture notes, use different applications, etc.)
Pre-Post Technology Survey

Students did feel more comfortable with iPads after a full term of using them during Autumn 2014 of Ohio Plants and Spring 2015 of Organismal Diversity. However, I did not observe this during the May 2015 term of Ohio Plants or Autumn 2015 term of Organismal Diversity. I propose that the reason we did not see larger shifts in comfort levels with iPads can be explained by the two following options: 1) students came into the classroom already fairly comfortable with the technology or 2) students used the iPads when necessary, but did not utilize them enough to increase their comfort with the technology adequately.

Overall, students did not change their agreement with the statements on the post surveys about various aspects of the iPad use being beneficial to their learning. I also found that during the Autumn 2014 of Ohio Plants and Spring 2015 of Organismal Diversity terms that students shifted to disagreeing that many aspects of iPad use were beneficial to their learning. My results counter what other studies involving iPads have reported that student engagement and perception of achievement has increased (George et al., 2013; Gong & Wallace, 2012; Martin & Ertzberger, 2013; Mayfield et al., 2013; Rossing et al., 2012; Wilkinson & Barter, 2015). I offer three possible explanations for this:

1) students responded negatively when iPads were mandatory for use (Figure 13),
2) students readily recognized the pitfalls of the iPads, and
3) the studies that have been conducted did not focus solely on discipline-specific and studio-based courses like Ohio Plants and Organismal Diversity. Because
studio-based courses already implement many hands-on activities and discussions regularly, students may have viewed iPads as unnecessary in this context.

**Hypothesis: iPads as digital field notebooks**

My results do not support the hypothesis that if students use iPads as digital field notebooks that they will record more educational content (i.e., words and pictures) and, subsequently, score higher on summative assessments relating to the field exercise (i.e., the Gymnosperm exercise) than students who utilized traditional pencil-and-paper notebooks. I found this to be the case in both of the biology classes, Ohio Plants and Organismal Diversity, in which I conducted the study. While other mobile technologies used as note-taking devices, such as laptop computers, increase the amount of information gathered, this increase does not correspond to greater synthesis or performance (Mueller & Oppenheimer, 2014). In contrast, my findings show that students gather the same amount of information with iPads as traditional means. I suggest that educators can still incorporate technology such as iPads into their classrooms without negatively affecting student performance.

There were paradoxical relationships between student attitudes on mobile technology and learning gains. If students were more comfortable with Apple computers (technology survey question 10) at the beginning of the term, they earned fewer points on the summative assessment questions for the Gymnosperm exercise. I also found in Ohio Plants, if students felt that iPads used as digital laboratory notebooks would be beneficial to their learning (technology survey question 12) at the beginning of the term, they
earned more points on the summative assessment questions for the Gymnosperm exercise.

Lastly, I did find that students in Ohio Plants during the May 2015 term scored significantly higher on the Gymnosperm exercise summative assessments than students did in either the Autumn 2014 or Autumn 2015 semesters. Because I determined that the word counts and picture counts were not different among all three semesters, I can rule out the presence of iPads during that term as a cause for the discrepancy. Instead, I proposed that students during a May term of course might have scored better because 1) students who take courses in a May term have only one course on which to focus or 2) typically students who take courses in a May term may have more motivation for taking the course than those students who take it during the regular term. I have provided select student demographic data from the Autumn and May courses of Ohio Plants in the Appendix (Figures L.1 through L.3).

*Hypothesis: iPads as digital sharing devices*

Initially, students did not share many findings within the morning and afternoon sections of Organismal Diversity Spring 2015 throughout the first four weeks of the semester, regardless of the type of sharing, either through the screens or the “traditional” way. Additionally, the instructors of Organismal Diversity in Autumn 2015 also noticed that students hesitated to share through either means during the beginning of the semester. I found these hesitations by the students to share surprising given that they were instructed to share with at least one other group, that sharing facilitates a broader
understanding of the studied organisms, and historically that the studio set-up of Organismal Diversity led to students sharing right away in the course.

My results do not support the hypothesis that if students used iPads as digital sharing devices, they would gather and share more raw data with their peers than students who used traditional means of sharing, and would subsequently score higher on related summative assessments.

For this portion of my study, I evaluated the three instructional units in Organismal Diversity. I did find a significant difference in total words recorded during the Arthropod unit between the students enrolled in the Autumn 2015 (iPads present) section and the Spring 2015 AM (iPads absent) and Spring 2015 PM (iPads present) sections. However, student sharing did not account for this difference, as total shared words across the three sections of Organismal Diversity did not differ. This difference may be due to differences in student cohorts or due to instructor variance. While there were two instructors during both terms of Spring 2015, only one of the instructors from that term taught Organismal Diversity solely in Autumn 2015. I also found no difference in total shared words, total shared pictures, and total table visits across the three semesters for the Ground-Dwelling Invertebrate and Mollusks units.

While I did not find a difference in total shared words or total table visits during the Arthropod unit, I did find an increase in total shared pictures. However, this difference may be because the mean total shared pictures for the Autumn 2015 section was zero. Even when provided with two different methods (traditional and screen) by which students could share their findings with one another in the iPad class sections, students with iPad access did not share more information than students who utilized the
traditional method of sharing. Perhaps, as students indicated on the open-ended questions, students liked having the option to share but did not necessarily always feel the need to share information. However, I cannot say that students did not want to share at all, as they likely failed to indicate all of the instances in which they shared information.

Conclusion

Based on empirical data and student opinions, I suggest educators should avoid simply using technology as replacement for traditional field or laboratory notebooks or for sharing in place of traditional means. Other work suggests many ways in which to utilize iPads and their applications in both chemistry (Morsch & Lewis, 2015; Silverberg, Tierney, & Bodek, 2014) and biology (Stark, 2012), but fails to explicitly explain how the technology will impact targeted student learning outcomes. While my study reveals some of the strengths and weaknesses of mobile learning technologies such as the Apple iPad, I suggest that educators continue to conduct empirical studies in which they evaluate the potential learning benefits of iPad incorporation into biology (and other) classrooms. Incorporation of mobile learning technologies is a costly endeavor for universities, educators, and students so educators need to have clear lines of evidence to support the financial investment used to obtain and implement these mobile learning technologies.
Table 3.1. Participation rates for iPad study

<table>
<thead>
<tr>
<th>Class and section</th>
<th>iPad Treatment/Control</th>
<th># or participants ( % of total enrollment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ohio Plants Autumn 14</td>
<td>Treatment</td>
<td>31 (100%)</td>
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<tr>
<td>Ohio Plants May 15</td>
<td>Treatment</td>
<td>24 (96%)</td>
</tr>
<tr>
<td>Ohio Plants Autumn 15</td>
<td>Control</td>
<td>30 (100%)</td>
</tr>
<tr>
<td>Org Div. Spring 15 Section 1</td>
<td>Control</td>
<td>22 (81%)</td>
</tr>
<tr>
<td>Org Div. Spring 15 Section 2</td>
<td>Treatment</td>
<td>49 (94%)</td>
</tr>
<tr>
<td>Org Div. Autumn 15</td>
<td>Treatment</td>
<td>25 (86%)</td>
</tr>
</tbody>
</table>

Table 3.2. Statements used as predictors for increased gathering of raw data (i.e., number of words and pictures recorded) by students who used iPads in Ohio Plants and Organismal Diversity.

<table>
<thead>
<tr>
<th>Question #</th>
<th>Statement Text</th>
<th>Predicted Change</th>
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</thead>
<tbody>
<tr>
<td>9</td>
<td>Please indicate your level of comfort with iPads.</td>
<td>+</td>
</tr>
<tr>
<td>10</td>
<td>Please indicate your level of comfort with Apple computers.</td>
<td>+</td>
</tr>
<tr>
<td>12</td>
<td>I feel that using iPads in class as a digital laboratory notebook would be beneficial to my learning.</td>
<td>+</td>
</tr>
<tr>
<td>13*</td>
<td>I feel that using iPads in class as a sharing device would be beneficial to my learning.</td>
<td>+</td>
</tr>
</tbody>
</table>

*We only used this question as predictors of sharing with iPads in Organismal Diversity.
Figure 3.1. Boxplots of number of words written using a traditional notebook (control) or written/recorded using an iPad (treatment) during the Gymnosperm exercise by students in Ohio Plants over three terms. No significant treatment effect was evident (one-way ANOVA, p > 0.05).
Figure 3.2. Boxplots of number of pictures sketched using a traditional notebook (control) or taken/sketched using an iPad (treatment) during the Gymnosperm exercise by students in Ohio Plants over three semesters. No significant treatment effect was evident (one way ANOVA, p > 0.05).
Figure 3.3. Boxplots of summative scores on quiz questions relating to the learning objectives of the Gymnosperm exercise by students in Ohio Plants over three terms.

Different letters associated with means indicate a significant difference between means (p ≤ 0.05, Fisher’s LSD).
Table 3.3. Student raw data recorded during the Gymnosperm exercise (i.e., word and picture counts) and summative scores relating to learning objectives of Gymnosperm exercise by students in Ohio Plants. We report the mean plus standard deviations in parentheses.

Different letters associated with means indicate a significant difference between means (p ≤ 0.05, Fisher’s LSD).

<table>
<thead>
<tr>
<th>Student Products</th>
<th>Control</th>
<th>Treatment</th>
<th>F statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AU ’15</td>
<td>AU ’14</td>
<td>May ‘15</td>
<td></td>
</tr>
<tr>
<td>Words Written/Recorded</td>
<td>76.5 (37.7)</td>
<td>58.8 (37.6)</td>
<td>63.4 (45.1)</td>
<td>$F_{(2, 70)} = 1.426$</td>
</tr>
<tr>
<td>Pictures Sketched/Taken</td>
<td>7.5 (2.6)</td>
<td>7.2 (2.1)</td>
<td>7.1 (2.3)</td>
<td>$F_{(2, 70)} = 0.214$</td>
</tr>
<tr>
<td>Summative Score (%)</td>
<td>85.1a (9.0)</td>
<td>78.6b (13.5)</td>
<td>92.5c (11.8)</td>
<td>$F_{(2, 70)} = 7.999$</td>
</tr>
</tbody>
</table>
Figure 3.4. Mean summative scores on quiz questions relating to Gymnosperm exercise learning objectives (presented with 95% confidence intervals) grouped by student answers to the comfort level question about Apple computers (pre-technology survey question number 10) in Ohio Plants.

Different letters associated with means indicate a significant difference between means (p ≤ 0.05, Fisher’s LSD).
**Figure 3.5.** Mean summative scores on quiz questions relating to Gymnosperm Exercise learning objectives (presented with 95% confidence intervals) grouped by student agreement to benefits of using iPad as a digital laboratory notebook (pre-technology survey question number 12) by students in Ohio Plants.

Different letters associated with means indicate a significant difference between means (p ≤ 0.05, Fisher’s LSD).
Figure 3.6. Boxplots of words written (control) or written/recorded (treatment) during the Gymnosperm exercise by students in Organismal Diversity for three separate class sections over two terms. No significant treatment effect was evident (one-way ANOVA, p > 0.05).

Figure 3.7. Boxplots of pictures sketched (control) or taken/sketched (treatment) during the Gymnosperm exercise by students in Organismal Diversity for three separate class sections over two terms. No significant treatment effect was evident (one-way ANOVA, p > 0.05).
Figure 3.8. Boxplots of summative scores on quiz questions relating to the learning objectives of the Gymnosperm exercise by students in Organismal Diversity for three separate class sections over two terms. No significant treatment effect was evident (p > 0.05).

Table 3.4. Student raw data recorded during the Gymnosperm exercise (i.e., word and picture counts) and summative scores relating to learning objectives of Gymnosperm exercise by students in Organismal Diversity. We report the mean plus standard deviations in parentheses.

<table>
<thead>
<tr>
<th>Student Products</th>
<th>Control</th>
<th>Treatment</th>
<th>F statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SP ’15 (AM)</td>
<td>SP ’15 (PM)</td>
<td>AU ’15</td>
<td></td>
</tr>
<tr>
<td>Words Written/Recorded</td>
<td>132.2 (35.9)</td>
<td>167.2 (76.8)</td>
<td>131.4 (124.2)</td>
<td>$F_{(2,68)} = 1.618$</td>
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<tr>
<td>Pictures Sketched/Taken</td>
<td>9.2 (5.2)</td>
<td>7.5 (2.5)</td>
<td>7.9 (1.8)</td>
<td>$F_{(2,67)} = 1.543$</td>
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<tr>
<td>Summative Score (%)</td>
<td>75.9 (11.2)</td>
<td>79.1 (12.2)</td>
<td>76.3 (14.3)</td>
<td>$F_{(2,68)} = 0.530$</td>
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</table>
Figure 3.9. Boxplots of total words recorded during the Arthropod unit by students in Organismal Diversity for three separate class sections over two terms.

Different letters associated with means indicate a significant difference between means ($p \leq 0.05$, Fisher’s LSD).

AU ’15, n = 16; SP ’15 AM, n = 21; SP ’15 PM, n = 39
Table 3.5. Student raw data recorded during three selected instructional units (i.e., word and picture counts) and summative scores relating to learning objectives of those units. We report the mean plus standard deviations in parentheses.

Unit A = Ground-Dwelling Invertebrates, Unit B = Mollusks, Unit C = Arthropods

<table>
<thead>
<tr>
<th>Unit</th>
<th>Student Products</th>
<th>Control</th>
<th>Treatment</th>
<th>F statistic</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SP '15 AM</td>
<td>SP '15 PM</td>
<td>AU '15</td>
<td>F (2,71)</td>
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<tr>
<td></td>
<td>Total Words</td>
<td>136.1 (74.2)</td>
<td>148.7 (107.3)</td>
<td>151.4 (79.7)</td>
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<td>Total Sketches</td>
<td>3.5 (1.0)</td>
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<td>n/a</td>
<td>n/a</td>
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<td>Unit B</td>
<td>Total Words</td>
<td>192.9 (98.1)</td>
<td>198.7 (136.7)</td>
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<td>Total Sketches</td>
<td>4.4 (2.1)</td>
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<td>Summative Score</td>
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<td>90.5 (16.0)</td>
<td>84.4 (8.5)</td>
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<td>Unit C</td>
<td>Total Words</td>
<td>237.4 (136.3)</td>
<td>221.3 (149.8)</td>
<td>426.0 (171.6)</td>
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<td>Total Sketches</td>
<td>4.6 (1.6)</td>
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<td>Summative Score</td>
<td>70.0 (23.7)</td>
<td>74.6 (16.2)</td>
<td>71.4 (12.0)</td>
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Table 3.6. Student total (i.e., traditionally plus screen) shared raw data recorded during three selected instructional units (i.e., shared word count, shared picture count, and tables visited). We report the mean plus standard deviations in parentheses.

Different letters associated with means indicate a significant difference between means (p ≤ 0.05, Fisher’s LSD).

Unit A = Ground-Dwelling Invertebrates, Unit B = Mollusks, Unit C = Arthropods

<table>
<thead>
<tr>
<th>Unit</th>
<th>Student Products</th>
<th>Control SP ’15 AM</th>
<th>Control SP ’15 PM</th>
<th>Control AU ’15</th>
<th>F statistic (df)</th>
<th>p value</th>
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<td>1.5 (1.2)</td>
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<td>F(2, 35) = 0.709</td>
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<td>Shared Sketches</td>
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<td>F(2, 35) = 2.724</td>
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<td>1.5 (0.6)</td>
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70
Table 3.7. Mean ratings of answers on indicated Likert-type questions from the technology survey concerning student comfort with PCs, Apple, and iPad technologies in Ohio Plants before and after a full semester of iPad use.

1 = Not Comfortable at all, 2 = Somewhat Comfortable, and 3 = Very Comfortable

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<th>Z score</th>
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<th>Effect size (r)</th>
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Table 3.8. Mean ratings of answers on indicated Likert-type questions from the technology survey concerning student comfort with PCs, Apple, and iPad technologies in Organismal Diversity before and after a full semester of iPad use.

1 = Not Comfortable at all, 2 = Somewhat Comfortable, and 3 = Very Comfortable

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<thead>
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<th>After</th>
<th>SD</th>
<th>Z score</th>
<th>p-value</th>
<th>Effect size (r)</th>
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<table>
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<th>After</th>
<th>SD</th>
<th>Z score</th>
<th>p-value</th>
<th>Effect size (r)</th>
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<td>0.5123</td>
<td>2.625</td>
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Table 3.9. Mean ratings of answers on indicated Likert-type questions from the technology survey concerning student perceived benefits of iPads on various aspects of learning in Ohio Plants before and after a full semester of iPad use.

Note: Questions 13 and 15-17 did not appear on the pre-post technology survey during AU’14 of Ohio Plants.

We reported effect sizes—r—as 0.1 (small), 0.3 (medium), and 0.5 (large) (Cohen 1988).

<table>
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<tr>
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<th>SD</th>
<th>Z score</th>
<th>p-value</th>
<th>Effect size (r)</th>
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<tbody>
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<td>-</td>
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<table>
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<th>SD</th>
<th>Z score</th>
<th>p-value</th>
<th>Effect size (r)</th>
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<td>3.667</td>
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Figure 3.10. Changes in mean ratings on indicated Likert-type questions from the technology survey concerning student perceived benefits of iPads on various aspects of learning in Ohio Plants before and after a full semester of iPad use. The max possible rating is 5—strongly agree—however, the graph has been extended to 6 to illustrate fully the standard deviations for some of the statements.

Ohio Plants AU ’14, n = 19; Ohio Plants May ’15, n = 12

*Note: Statements with an asterisk were not present on the technology survey during the AU’14 term of Ohio Plants
Table 3.10. Mean ratings of answers on indicated Likert-type questions from the technology survey concerning student perceived benefits of iPads on various aspects of learning in Organismal Diversity before and after a full semester of iPad use.

We reported effect sizes—\( r \)—as 0.1 (small), 0.3 (medium), and 0.5 (large) (Cohen 1988).

<table>
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<th>Org Div SP '15</th>
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<th>After SD</th>
<th>Z score</th>
<th>p-value</th>
<th>Effect size (r)</th>
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<td>2.800</td>
<td>-3.798</td>
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<td>0.7334</td>
<td>2.775</td>
<td>-4.713</td>
<td>( p &lt; 0.001 )</td>
<td>-0.5272</td>
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<td>40</td>
<td>3.475</td>
<td>0.9868</td>
<td>3.525</td>
<td>-0.301</td>
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<td>( p &lt; 0.001 )</td>
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<td>( p = 0.103 )</td>
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<th>After SD</th>
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Figure 3.11. Changes in mean ratings on indicated Likert-type questions from the technology survey concerning student perceived benefits of iPads on various aspects of learning in Organismal Diversity before and after a full semester of iPad use. The max possible rating is 5—strongly agree—however, the graph has been extended to 6 to illustrate fully the standard deviations for some of the statements.

Org Div SP’15, n = 40; Org Div AU’15, n = 16
Table 3.11. Comparison of pre-post gains on the technology survey questions 12-18 between students in Organismal Diversity after a use of iPads for an entire semester (SP ‘15 and AU ’15). Z scores and p-values reflect the results of Mann-Whitney U tests.

We reported effect sizes with 0.1 (small), 0.3 (medium), and 0.5 (large) (Cohen 1988).

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<th>Question</th>
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<th>SD</th>
<th>Z-score</th>
<th>p-value</th>
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<td>1.137</td>
<td>1.137</td>
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<td>p = 0.004</td>
<td>-0.3852</td>
</tr>
<tr>
<td></td>
<td>AU '15</td>
<td>16</td>
<td>0.063</td>
<td>1.124</td>
<td>1.124</td>
<td>-2.883</td>
<td>p = 0.004</td>
<td>-0.3852</td>
</tr>
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<td>SP '15</td>
<td>40</td>
<td>-1.250</td>
<td>1.127</td>
<td>1.127</td>
<td>-2.883</td>
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<td>-0.3852</td>
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<tr>
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<td>AU '15</td>
<td>16</td>
<td>-0.500</td>
<td>1.265</td>
<td>1.265</td>
<td>-2.883</td>
<td>p = 0.004</td>
<td>-0.3852</td>
</tr>
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<td>0.050</td>
<td>1.176</td>
<td>1.176</td>
<td>-2.883</td>
<td>p = 0.004</td>
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<tr>
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<td>AU '15</td>
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<td>0.750</td>
<td>0.856</td>
<td>0.856</td>
<td>-2.883</td>
<td>p = 0.004</td>
<td>-0.3852</td>
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<td>-2.883</td>
<td>p = 0.004</td>
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<td>1.518</td>
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<td>-2.883</td>
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<td>-0.3852</td>
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<td>-2.883</td>
<td>p = 0.004</td>
<td>-0.3852</td>
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</table>
Figure 3.12. Percentage of total student responses to Q20 from both Ohio Plants and Organismal Diversity students. (Ohio Plants n=12 students)

Figure 3.13. Percentage of total student responses to Q21 from both Ohio Plants and Organismal Diversity students.

*The final three categories; “Use iPads exclusively”, “Increase Screen Sharing”, and “Photo Incorporation” are exclusive to Organismal Diversity.

(Ohio Plants n=12 students; Organismal Diversity n = 61 students).
Chapter 4: Conclusion

In this thesis, I followed the recommendations to continue discipline-based research in undergraduate biology education to develop and assess methodologies for effective biology teaching. In my studies, I investigated biodiversity education and mobile learning technology implementation at The Ohio State University. First, I developed and evaluated a new inquiry-based biodiversity exercise in Biology 1101: Introductory Biology for non-majors. Next, I assessed the use of Apple iPads as digital field notebooks and digital sharing devices in two biology courses within the Department of Evolution, Ecology, and Organismal Biology (EEOB)—EEOB 2210: Ohio Plants and EEOB 3320: Organismal Diversity. I provide a summary of the finding for each study below:

1) Students who completed my new inquiry-based field biodiversity exercise had a better awareness of ground-dwelling invertebrate diversity by having a greater gain in recognition of ground-dwelling invertebrates than students who completed the traditional biodiversity exercise had. Additionally, the students who completed my new inquiry-based field biodiversity exercise had more positive attitudes towards fieldwork and hands-on activities than students who completed the traditional biodiversity exercise did.

2) Overall, the presence of iPads used as digital field notebooks or digital sharing devices did not directly affect student outcomes positively or negatively in either EEOB 2210: Ohio Plants or EEOB 3320: Organismal Diversity. In other words, students did not gather more educational content (i.e., word and picture counts)
or score higher on summative assessments relating to assignments completed with use of the iPads. Students initially felt that iPads would be beneficial to their learning by agreeing with the statements on the technology survey. However, after completion of an entire term with access to iPads, students did not feel the iPads were beneficial to their learning. Ultimately, students used the iPads and recognized some novelties to their uses, but did not readily use them.

I found that the participation rates did vary between the two studies. The participation rate of the biodiversity study was about 37%. The participation rate of the iPad study ranged from 80-100%. I propose three explanations for this finding:

1) Students enrolled in the biodiversity study were non-major introductory students whereas the students in iPad study were biology majors. Major students might be more inclined to take the study seriously, as they typically are more invested in their biology courses.

2) I had better access to the students in the Ohio Plants and Organismal Diversity class. For both classes, I knew the instructors well and had been involved in some capacity in the courses previously. Because of my familiarity with both the courses and the instructors, I was able to come into the classroom more often to give reminders about completing the research materials for the study.

3) Different incentives for each study. The course instructor for Bio 1101 awarded regular course credit to complete the pre-post biodiversity surveys. However, for the iPad study, the instructors offered extra credit
for completing the pre-post technology surveys. By offering extra credit, students may be more enticed to complete surveys.

The results of the biodiversity education study contribute to the body of literature that supports the use of inquiry-based pedagogical methods to achieve learning goals and to increase student confidence in fieldwork. However, future biodiversity education studies should continue to develop, refine, and validate additional assessments to measure student understanding of local biodiversity. Additionally, for exercises such as this, instructor familiarity was key. For students who completed the new biodiversity exercise, I provided additional training on both the teaching methods employed and the content covered. While teaching assistants (TAs) usually receive training on any laboratory exercises that they teach in the Center for Life Science Education, these TAs are drawn from a variety of different biology departments. Because these TAs come from very specialized departments, they often are uncomfortable with teaching topics outside of their area of specialization. The specialized training that I provided could be beneficial. I recommend that future studies should also include an evaluation of any teaching assistant preparation components.

The results of the iPad study bolster the need for more work in the evaluation of mobile learning technology in not only undergraduate biology education, but also undergraduate education at large. While this study focused on the evaluation of two specific aspects of iPad usage—as digital field notebooks and digital sharing devices—future studies should evaluate additional aspects of iPad usage. Furthermore, since these studies occurred in rather content specific biology courses, future research should be
conducted in generalized biology courses at the undergraduate level for both majors and non-majors.
References


9322-1


Appendix A: Chapter 2 Supplementary Materials

Table A.1. Timeline of development and piloting of new biodiversity exercise and survey instrument.

<table>
<thead>
<tr>
<th>Semester</th>
<th>New biodiversity exercise</th>
<th>Survey instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autumn 2013</td>
<td>Initial development of exercise for EEOB 3320 class. Exercise primarily focused only on arthropod diversity.</td>
<td>Initial development.</td>
</tr>
<tr>
<td>Spring 2014</td>
<td>Piloting of exercise with EEOB 3320 class.</td>
<td>Piloting to measure student understanding and recognition of arthropod diversity and attitudes towards the new exercise.</td>
</tr>
<tr>
<td>Summer 2014</td>
<td>Minor revisions to exercise before administration to EEOB 3320.</td>
<td>Minor revisions and administration. Addition of CLASS-Bio questions to examine student ability to make connections between biology coursework and the real world.</td>
</tr>
<tr>
<td>Autumn 2014</td>
<td>Major revisions: Shift of focus to ground-dwelling invertebrate diversity (additional phyla coverage). Shift of focus from EEOB 3320 audience to Introductory Biology course; revision of learning objectives. New write-ups of activities developed for BIO 1101 class (student and TA versions).</td>
<td>Major revisions: Questions added to measure student understanding and recognition of ground-dwelling invertebrate diversity. Questions added to measure student attitudes toward fieldwork efficacy on their own learning.</td>
</tr>
<tr>
<td>Spring 2015</td>
<td>Final version administered.</td>
<td>Final version administered.</td>
</tr>
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</table>
Table A.2. Mean ratings of answers to Likert-type questions measuring student attitudes towards fieldwork effectiveness on their learning from students in BIO 1101: Introductory Biology for Non-Majors before and after completing the traditional or new biodiversity exercise.

<table>
<thead>
<tr>
<th>Traditional exercise</th>
<th>Question</th>
<th>N</th>
<th>Before</th>
<th>SD</th>
<th>After</th>
<th>SD</th>
<th>Test statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>47</td>
<td></td>
<td>46</td>
<td>3.696</td>
<td>1.0300</td>
<td>3.761</td>
<td>0.9472</td>
<td>t_{45} = -0.503</td>
<td>p = 0.617</td>
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<td>48</td>
<td></td>
<td>46</td>
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<td>0.9603</td>
<td>3.933</td>
<td>0.8367</td>
<td>t_{45} = -0.670</td>
<td>p = 0.506</td>
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<tr>
<td>49</td>
<td></td>
<td>46</td>
<td>4.000</td>
<td>0.8165</td>
<td>3.957</td>
<td>0.7290</td>
<td>t_{45} = 0.321</td>
<td>p = 0.749</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>46</td>
<td>3.435</td>
<td>0.9105</td>
<td>3.391</td>
<td>0.9062</td>
<td>t_{45} = 0.330</td>
<td>p = 0.743</td>
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</table>

<table>
<thead>
<tr>
<th>New exercise</th>
<th>Question</th>
<th>N</th>
<th>Before</th>
<th>SD</th>
<th>After</th>
<th>SD</th>
<th>Test statistic</th>
<th>p-value</th>
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<tr>
<td>47</td>
<td></td>
<td>61</td>
<td>4.033</td>
<td>0.8158</td>
<td>4.115</td>
<td>0.9147</td>
<td>t_{60} = -0.711</td>
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<td>48</td>
<td></td>
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<td>3.952</td>
<td>0.8949</td>
<td>4.355</td>
<td>0.6798</td>
<td>t_{61} = -2.4</td>
<td>p &lt; 0.001</td>
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<td>62</td>
<td>3.968</td>
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<td>50</td>
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<td>3.548</td>
<td>1.0191</td>
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<td>0.9832</td>
<td>t_{61} = -2.414</td>
<td>p = 0.019</td>
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<tr>
<td>51*</td>
<td></td>
<td>62</td>
<td>-</td>
<td>-</td>
<td>3.661</td>
<td>0.7230</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

For answers: 1 = strongly disagree, 3 = neutral, and 5 = strongly agree

*Question 51 appears on the post-exercise survey for both the traditional and new biodiversity exercises; however, those who did not complete the traditional exercise selected “not-applicable”
Table A.3. Mean ratings of answers to Likert-type questions measuring student ability to make real world connections to their study of biology. “Real world connections” question cluster (Semsar et al., 2011) and question 14 answers from students in BIO 1101: Introductory Biology for Non-Majors before and after completing the traditional or new biodiversity exercise.

<table>
<thead>
<tr>
<th>Traditional exercise</th>
<th>Question</th>
<th>N</th>
<th>Before</th>
<th>SD</th>
<th>After</th>
<th>SD</th>
<th>Test statistic</th>
<th>p-value</th>
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<td>1.0532</td>
<td>46</td>
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<td>0.9651</td>
<td>3.022</td>
<td>0.9773</td>
<td>46</td>
<td>t_{45} = -0.621</td>
<td>p = 0.538</td>
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<tr>
<td>26</td>
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<td>1.0946</td>
<td>3.130</td>
<td>1.0458</td>
<td>46</td>
<td>t_{45} = -0.550</td>
<td>p = 0.585</td>
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<tr>
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<td>46</td>
<td>3.978</td>
<td>0.5769</td>
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<td>46</td>
<td>t_{45} = 1.855</td>
<td>p = 0.070</td>
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<tr>
<td>30</td>
<td>46</td>
<td>4.022</td>
<td>0.7146</td>
<td>3.978</td>
<td>0.7450</td>
<td>46</td>
<td>t_{45} = 0.405</td>
<td>p = 0.688</td>
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<tr>
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<td>46</td>
<td>3.370</td>
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<td>0.9158</td>
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<td>t_{45} = 0.535</td>
<td>p = 0.596</td>
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<tr>
<td>32</td>
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<td>0.9593</td>
<td>2.217</td>
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<td>39</td>
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<td>t_{45} = -1.124</td>
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</table>

<table>
<thead>
<tr>
<th>New exercise</th>
<th>Question</th>
<th>N</th>
<th>Before</th>
<th>SD</th>
<th>After</th>
<th>SD</th>
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<tbody>
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<td>14</td>
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<td>t_{61} = 2.0325</td>
<td>p &lt; 0.001</td>
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<tr>
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<td>t_{61} = 2.0325</td>
<td>p = 0.908</td>
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<tr>
<td>26</td>
<td>62</td>
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<td>1.0222</td>
<td>3.274</td>
<td>1.0890</td>
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<td>t_{61} = -0.711</td>
<td>p = 0.170</td>
</tr>
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<td>0.6800</td>
<td>3.952</td>
<td>0.8184</td>
<td>61</td>
<td>t_{61} = -2.4</td>
<td>p = 0.470</td>
</tr>
<tr>
<td>30</td>
<td>62</td>
<td>3.774</td>
<td>0.8380</td>
<td>3.919</td>
<td>0.8356</td>
<td>61</td>
<td>t_{61} = -2.414</td>
<td>p = 0.118</td>
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<tr>
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<td>62</td>
<td>3.435</td>
<td>0.8985</td>
<td>3.339</td>
<td>1.0234</td>
<td>61</td>
<td>t_{61} = -2.414</td>
<td>p = 0.458</td>
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<tr>
<td>33</td>
<td>62</td>
<td>2.113</td>
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<td>2.048</td>
<td>0.9823</td>
<td>61</td>
<td>t_{61} = -2.414</td>
<td>p = 0.597</td>
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<tr>
<td>39</td>
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<td>2.148</td>
<td>0.8532</td>
<td>2.262</td>
<td>0.8347</td>
<td>60</td>
<td>t_{60} = -2.414</td>
<td>p = 0.301</td>
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</table>

For answers: 1 = strongly disagree, 3 = neutral, and 5 = strongly agree
Figure A.1. Frequencies of student responses to question 48 before and after completion of the traditional or new biodiversity exercise. Traditional exercise n = 46; new exercise n = 62

Figure A.2. Frequencies of student responses to question 49 before and after completion of the traditional or new biodiversity exercise. Traditional exercise n = 46; new exercise n = 62
Figure A.3. Frequencies of student responses to question 50 before and after completion of the traditional or new biodiversity exercise. Traditional exercise n = 46; new exercise n = 62.

Figure A.4. Frequencies of student responses to question 14 before and after completion of the traditional or new biodiversity exercise. Traditional exercise n = 46; new exercise n = 62.
Figure A.5. Frequencies of student responses to question 33 before and after completion of the traditional or new biodiversity exercise. Traditional exercise n = 46; new exercise n = 62.
Appendix B: Pre-Post Biodiversity Survey

Survey Instrument (Question 51 only appears on the post-exercise survey)

1) Do you consent to participate in the study?
   a. Yes, I consent to the research.
   b. No, I do not consent to the research

2) Please provide your name.number (e.g. buckeye.1) so that the researchers can report who has taken the survey for course points to the appropriate instructor. We will remove this information from your responses once the research team has reported your participation in the surveys.

3) Please provide your first initial of your first, middle, and last name with the last two digits of your year of birth (e.g. RTB 91 in place of Rob Thomas Buckeye 1991).

4) What is your approximate GPA?
   a. 3.5 – 4.0
   b. 3.0 – 3.49
   c. 2.5 – 2.99
   d. 2.0 – 2.49
   e. Below 2.0

5) What is your current area of study or major?

6) What is your gender?
   a. Male
   b. Female

7) What is your race/ethnicity? (drop down menu of choices)
   a. Caucasian (White)
   b. African American
   c. Native American
   d. Asian
   e. Hispanic
   f. Pacific Islander
   g. Other

8) How many biology courses (in college and high school) have you taken?
   a. This is my first
   b. Two
   c. Three
   d. Four
9) What is your current rank?
   a. First year
   b. Second year
   c. Third year
   d. Fourth year
   e. Fifth year
   f. Graduate Student
   g. Non-degree student
   h. None of the above

10) List 5 different animal species (common names are acceptable) that you can expect to find around OSU’s campus. As an example to help you understand the format: instead of writing “mammal”, write “red kangaroo” or “Macropus rufus”.

11) What kinds of locations on OSU’s campus might you expect to find the most animal diversity? (List 3 locales and describe briefly – less than 5 words – why you believe it is a good locale for diversity.)

12) Which group(s) of animal do you think are most abundant (i.e., greatest number of animal species per group in many of the world’s ecosystems)?

13) There is more macro-diversity contained on the branches of a tree (e.g. a pine tree) than there is non-bacterial micro-diversity on or in the soil below that tree.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

14) I do not feel that I have many interactions with biodiversity in my daily life.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

15) My curiosity about the living world led me to study biology.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

16) I think about the biology I experience in everyday life.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

17) After I study a topic in biology and feel that I understand it, I have difficulty applying that information to answer questions on the same topic.
18) Knowledge in biology consists of many disconnected topics.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

19) When I am answering a biology question, I find it difficult to put what I know into my own words.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

20) I do not expect the rules of biological principles to help my understanding of the ideas.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

21) To understand biology, I sometimes think about my personal experiences and relate them to the topic being analyzed.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

22) If I get stuck on answering a biology question on my first try, I usually try to figure out a different way that works.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

23) I want to study biology because I want to make a contribution to society.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
24) If I don’t remember a particular approach needed for a question on an exam, there’s nothing much I can do (legally!) to come up with it.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
25) If I want to apply a method or idea used for understanding one biological problem to another problem, the problems must involve very similar situations.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
26) I enjoy figuring out answers to biology questions.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
27) It is important for the government to approve new scientific ideas before they can be widely accepted.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
28) Learning biology changes my ideas about how the natural world works.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
29) To learn biology, I only need to memorize facts and definitions.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
30) Reasoning skills used to understand biology can be helpful to my everyday life.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
31) It is a valuable use of my time to study the fundamental experiments behind
biological ideas.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
32) If I had plenty of time, I would take a biology class outside of my major
requirements just for fun.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
33) The subject of biology has little relation to what I experience in the real world.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
34) There are times I think about or solve a biology question in more than one way to
help my understanding.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
35) If I get stuck on a biology question, there is no chance I’ll figure it out on my
own.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
36) When studying biology, I relate the important information to what I already know
rather than just memorizing the way it is presented.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree
37) There is usually only one correct approach to solving a biology problem.
   a. Strongly agree
   b. Agree
   c. Neutral
38) When I am not pressed for time, I will continue to work on a biology problem until I understand why something works the way it does.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

39) Learning biology that is not directly relevant to or applicable to human health is not worth my time.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

40) Mathematical skills are important for understanding biology.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

41) I enjoy explaining biological ideas that I learn about to my friends.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

42) We use this statement to discard the survey of people who are not reading the questions. Please select agree (not strongly agree) for this question to preserve your answers.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

43) The general public misunderstands many biological ideas.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

44) I do not spend more than a few minutes stuck on a biology question before giving up or seeking help from someone else.
   a. Strongly agree
45) Biological principles are just to be memorized.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

46) For me, biology is primarily about learning known facts as opposed to investigating the unknown.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

47) If given the opportunity to have more outdoor field experiences in my biology classes, I feel that my education would benefit.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

48) I feel that use of fieldwork and/or manipulatives (i.e., hands-on activities) allow(s) me to notice/recognize the biodiversity around me more than purely lecture-based coursework.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

49) I feel that use of fieldwork and/or manipulatives (i.e., hands-on activities) allow(s) me to learn and understand the biodiversity around me more than purely lecture-based coursework.
   a. Strongly agree
   b. Agree
   c. Neutral
   d. Disagree
   e. Strongly disagree

50) I believe that if I were to collect organisms in their environment, I would better understand their ecological role rather than experiencing pre-collected, preserved specimens.
   a. Strongly agree
   b. Agree
c. Neutral
d. Disagree
e. Strongly disagree

51) After completing the Berlese Funnel Exercise, I feel that I can better notice and recognize the biodiversity around me.
a. Strongly agree
b. Agree
c. Neutral
d. Disagree
e. Strongly disagree
Appendix C: Berlese Funnel Exercise (Student Version)

What can we learn about arthropod diversity from local, urban environments?

Introduction
Arthropods make up a significant portion of the Earth’s animal biodiversity in many environments. Additionally, arthropods – specifically insects – have many traits that allow them to be so successful in those environments. If arthropods are ubiquitous (or everywhere), where can we find them? In this exercise, you will attempt to find locations on campus in which arthropod diversity exists and describe that diversity.

Objectives:

• To discover the abundant diversity of arthropods and other soil invertebrates on OSU’s campus.
• To recognize differences between arthropods and other soil invertebrates discovered around OSU’s campus.
• To experience biology and natural history as a processes of discovery through basic fieldwork.

Materials:

• A brown paper bag, two per lab group
• Berlese funnel apparatus, one per lab group
• Dissecting Scope, two per lab group
• Isopropyl alcohol
• Petri Dishes, two per group

Directions (Week 1):

• In groups of four, you will choose a location around Jennings Hall where you can find arthropod diversity. Make sure that your lab group chooses a different collecting site and substrate type, if possible, than the other groups in your lab.
• When you and your group choose a site, keep in mind materials that might hold arthropod diversity such as leaf litter, pine cones, etc.
• Once you have selected your location, you and your lab group should take appropriate field notes via observations in the section below before collecting any substrate for analysis back in lab.
• Additionally, remember that good field notes will allow another student that did not complete this lab to find your collection location, substrate type, and, ultimately, re-collect from that area (i.e., that student can perform your procedure).

Field Notes:

• Once you have completed your field notes, place your substrate samples in the brown paper bags provided.

• When you return to the lab, set up your Berlese funnel apparatus following your TA’s directions. Combine the contents of both bags. Next, place your lab group’s substrate into the Berlese funnel. You will examine the Berlese funnel results in two weeks.
Directions (Week 2):

- Collect the styrofoam cups from your Berlese funnels. You will need to pour the contents of the cup into two Petri dishes. Next, get a dissecting scope to examine your sample with a partner from your lab group of four. Answer the study questions below.

Study Questions:

1. In the space provided below, draw, describe, and label at least three specimens that you have found in your sample (be sure to provide size estimates when possible). We have provided enough space for you to draw and describe six organisms:

   - Some guiding questions to help you note differences:
     - How many segments do you notice?
     - Do you notice differences in mouthparts?
     - How do body appendages compare; how do they differ?

Organism 1:  
Organism 2:
• Use the provided identification materials to identify the organisms in your cup. Identify the organisms to the following taxonomic levels (these are common taxa that can be observed with Berlese funnels). You can place tally marks beside taxon names to represent the organisms found by your group. On the right hand side, P, SP, Cl, and O correspond to phylum, subphylum, class, and order, respectively.

<table>
<thead>
<tr>
<th>Organism</th>
<th>Taxonomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ants, Bees, Wasps</td>
<td>O: Hymnoptera</td>
</tr>
<tr>
<td>Beetles</td>
<td>O: Coleoptera</td>
</tr>
<tr>
<td>Flies, mosquitoes</td>
<td>O: Diptera</td>
</tr>
<tr>
<td>Termites</td>
<td>O: Isoptera</td>
</tr>
<tr>
<td>Barklice</td>
<td>O: Psocoptera</td>
</tr>
<tr>
<td>Springtails</td>
<td>O: Collembola</td>
</tr>
<tr>
<td>Proturans</td>
<td>O: Protura</td>
</tr>
<tr>
<td>Diplurans</td>
<td>O: Diplura</td>
</tr>
<tr>
<td>Jumping Bristletails</td>
<td>O: Microcoryphia</td>
</tr>
<tr>
<td>Garden centipedes</td>
<td>Cl: Symphyla</td>
</tr>
<tr>
<td>Mites, ticks</td>
<td>O: Acari</td>
</tr>
<tr>
<td>Spiders</td>
<td>Cl: Arachnida</td>
</tr>
<tr>
<td>Millipedes</td>
<td>Cl: Diplopoda</td>
</tr>
<tr>
<td>Centipedes</td>
<td>Cl: Chilopoda</td>
</tr>
<tr>
<td>Pillbugs</td>
<td>SP: Crustacea, O: Isopoda</td>
</tr>
<tr>
<td>Earthworms (segmented worms)</td>
<td>P: Annelida</td>
</tr>
<tr>
<td>Roundworms (non-segmented worms)</td>
<td>P: Nematoda</td>
</tr>
<tr>
<td>Snails, slugs</td>
<td>P: Mollusca, Cl: Gastropoda</td>
</tr>
</tbody>
</table>

• Once you have categorized your 3+ specimens with the help of laminated pictorial guides and/or TA assistance, record the number of specimens in the above specified taxonomic groups per your substrate on the provided excel data sheet. You will use the data generated to see how many different types of arthropods and other soil-dwelling invertebrates your lab section has found.

2. Compare and contrast samples within your lab section and choose one lab group with which to answer the following:
   a. What was the composition of your group’s sample? How did your sample differ in terms of results (i.e., what you found and how much) and collection substrate details (leaf duff versus pine cones) from a lab group with a different substrate type?
b. Refer to the section datasheet: Why might the type and number of organisms your group found be different from a group with a different collection type? Offer two plausible hypotheses to explain these differences. Your hypotheses should be based on your observations and field notes.
Appendix D: Berlese Funnel Exercise (TA Version)

What can we learn about arthropod diversity from local, urban environments?

Introduction

*INTRO LECTURE:*

Time = 10 minutes before having students set out to various sites on OSU’s campus around Jennings Hall.

Give brief introductory lecture with provided slides.

- Opening guiding question for lecture: Why have the arthropods been so successful?
- The first set of slides contains some pictures of the four living subphyla of arthropods – 1) centipedes and millipedes (myriapoda), 2) spiders, mites, and horseshoe crabs (chelicerates), 3) insects and allies (hexapoda), 4) shrimp and crabs (crustacea). I’ve provided general information about each group on the presenter notes on the accompanying Keynote slides.
- The slide has graphical representations and statistics of the abundance of arthropods in relation to other animal phyla, plants, etc. This information should help you to emphasize the sheer abundance of arthropods in the world.
- So, if arthropods are everywhere, where and how can we find them?

Arthropods make up a significant portion of the Earth’s animal biodiversity in many environments. Additionally, arthropods – specifically insects – have many traits that allow them to be so successful in those environments. If arthropods are ubiquitous (or everywhere), where can we find them? In this exercise, you will attempt to find locations on campus in which arthropod diversity exists and describe that diversity.
Objectives:

• To discover the abundant diversity of arthropods and other soil invertebrates on OSU’s campus.
• To recognize differences between arthropods and other soil invertebrates discovered around OSU’s campus.
• To experience biology and natural history as a processes of discovery through basic fieldwork.

Materials:

• A brown paper bag, two per lab group
• Berlese funnel apparatus, one per lab group
• Dissecting Scope, two per lab group
• Isopropyl alcohol
• Petri Dishes, two per group

Directions (Week 1) (Time = 30 minutes total):

• In groups of four, you will choose a location around Jennings Hall where you can find arthropod diversity. Make sure that your lab group chooses a different collecting site and substrate type, if possible, than the other groups in your lab.
• When you and your group choose a site, keep in mind materials that might hold arthropod diversity such as leaf litter, pine cones, etc.

Some successful sites in the past for substrate collection include: behind Campbell Hall (sweet gum fruits), around Mirror Lake (soil, pine cones, leaf duff), around Enarson/Hale Hall (different leaf duff than by Mirror Lake). Do not tell them to go to these sites specifically, but encourage students to think about which sites would hold arthropod diversity.

Time = 20 minutes for outdoor activities

IMPORTANT: Make sure that each lab group collects different substrate types and that each group collects only one substrate type between both bags they collect. At the least, make sure that the following types of substrates are collected: cones, leaf litter, soil, and possibly small twigs. This will allow students to compare and contrast their samples during the follow-up week.

Write down each group’s substrate type:

<table>
<thead>
<tr>
<th>Substrate Type</th>
</tr>
</thead>
</table>
• Once you have selected your location, you and your lab group should take appropriate field notes via observations in the section below before collecting any substrate for analysis back in lab.
• Additionally, remember that good field notes will allow another student that did not complete this lab to find your collection location, substrate type, and, ultimately, re-collect from that area (i.e., that student can perform your procedure).

Field Notes:
While in the field, circulate to make sure that students take field notes. Remind them that they need to record data such that someone who has not done this exercise can repeat their procedure.

Guiding questions:
What conditions might be useful to record? (Temperature, brief habitat description, time of day, location.)

• Once you have completed your field notes, place your substrate samples in the brown paper bags provided.

• When you return to the lab, set up your Berlese funnel apparatus following your TA’s directions. Combine the contents of both bags. Next, place your lab group’s substrate into the Berlese funnel. You will examine the Berlese funnel results in two weeks.
Time = 5-10 minutes for set-up
The provided Keynote slides have an introduction to the Berlese funnels. These slides will give students a brief background of the use of Berlese funnels. You should direct students to take one pop bottle, one regular Styrofoam cup, one Styrofoam cup base, and enough isopropyl alcohol to fill ¼ of the regular Styrofoam cup. See picture below for clarification. IMPORTANT = Make sure the students write their names and lab section on their Styrofoam cups.

Directions (Week 2): (TIME = 90 minutes total)

• Collect the styrofoam cups from your Berlese funnels. You will need to pour the contents of the cup into two Petri dishes. Next, get a dissecting scope to examine your sample with a partner from your lab group of four. Answer the study questions below.

The Berlese funnels should be back in the lab room. The Styrofoam cups have had isopropyl alcohol added to them over the past week to ensure that the collected specimens do not desiccate.

Have students split the contents of their Styrofoam cups into two petri dishes per lab group. Next, make sure that each pair of students has a dissecting scope. Make sure that students understand how to focus the scopes and look for their specimens in the petri dish.
Study Questions:

3. In the space provided below, draw, describe, and label at least three specimens that you have found in your sample (be sure to provide size estimates when possible). We have provided enough space for you to draw and describe six organisms:

- Some guiding questions to help you note differences:
  - How many segments do you notice?
  - Do you notice differences in mouthparts?
  - How do body appendages compare; how do they differ?

More space will appear here for students to sketch their specimens.

*This portion of the exercise should take ~ 40 minutes.*
Circulate through the room to help students notice the different between organisms that they find. Be sure to emphasize that they are looking for differences.

General guidelines to Arthropods: 6 legs = some sort of insect; 8 legs = some sort of arachnid
Students should see many different types of mites, spiders, springtails, centipedes/millipedes, pill bugs.
Additionally, students might find ants, earwigs, and small parasitoid wasps.

Small picture guides of arthropods and other soil-dwelling macro-invertebrates will be in the lab for you and your students to reference to help students identify the organisms they find. Remember, the goal is for students to recognize the many differences between their organisms.

There will be small field guides available for you and your students to use in the lab as well.

- Use the provided identification materials to identify the organisms in your cup. Identify the organisms to the following taxonomic levels (these are common taxa that can be observed with Berlese funnels). You can place tally marks beside taxon names to represent the organisms found by your group. On the right hand side, P, SP, Cl, and O correspond to phylum, subphylum, class, and order, respectively.
  - Ants, Bees, Wasps   O: Hymnoptera
o Beetles
  O: Coleoptera
o Flies, mosquitoes
  O: Diptera
o Termites
  O: Isoptera
o Barklice
  O: Psocoptera
o Springtails
  O: Collembola
o Proturans
  O: Protura
o Diplurans
  O: Diplura
o Jumping Bristletails
  O: Microcoryphia
o Garden centipedes
  Cl: Symphyla
o Mites, ticks
  O: Acari
o Spiders
  Cl: Arachnida
o Millipedes
  Cl: Diplopoda
o Centipedes
  Cl: Chilopoda
o Pillbugs
  SP: Crustacea, O: Isopoda
o Earthworms (segmented worms)
  P: Annelida
o Roundworms (non-segmented worms)
  P: Nematoda
o Snails, slugs
  P: Mollusca, Cl: Gastropoda

• Once you have categorized your 3+ specimens with the help of laminated pictorial guides and/or TA assistance, record the number of specimens in the above specified taxonomic groups per your substrate on the provided excel data sheet. You will use the data generated to see how many different types of arthropods and other soil-dwelling invertebrates your lab section has found.

4. Compare and contrast samples within your lab section and choose one lab group with which to answer the following:
   b. What was the composition of your group’s sample? How did your sample differ in terms of results (i.e., what you found and how much) and collection substrate details (leaf duff versus pine cones) from a lab group with a different substrate type?

Time = 35 minutes for the entirety of Question 2.
Again, circulate throughout the lab to make sure that students compare AND contrast their samples with another group. Make sure that if they had leaf duff under a maple tree, for example, that they have compared with a different substrate type and habitat such as pinecones under a pine tree.
c. Refer to the section datasheet: Why might the type and number of organisms your group found be different from a group with a different collection type? Offer two plausible hypotheses to explain these differences. Your hypotheses should be based on your observations and field notes.

Here, the students should speculate on the differences between substrates and what role these differences play on the distribution of organisms found. A group may wonder why they only found mites compared to another group that found springtails, spiders, and millipedes.

Ask them to tell you what a hypothesis is. Remember, that for their hypothesis to be plausible, it needs to be based on observations that they made from their field notes or sketches and notes from their observed specimens.

**WRAP-UP LECTURE:**
Time = 10-15 minutes
In the wrap-up lecture, you will show students pictures of commonly observed organisms in the Berlese funnel samples. Additionally, we will place the arthropods on a phylogenetic tree with trees from TimeTree.org.
**Refer to presenter notes for more detail.
Answer any questions about the overall activity.
Appendix E: Week 1 Slides for Berlese Funnel Exercise

Why have the Arthropods been so successful?

What are the four major subphyla?
1) Shrimp and Crabs (Crustacea)
2) Insects and allies (Hexapods)
3) Centipedes & Millipedes (Myriapods)
4) Spiders, Mites, etc. (Chelicerates)
Why have the Arthropods been so successful?

Some Arthropod Statistics

- Entire phylum = most speciose animal phylum

If Arthropods are everywhere, where and how can we find them?

- 1.1 million = number of known insect species
- May be 30 million living insect species!

What can we learn about Arthropod diversity from local, urban environments?

Directions (Day 1):

In groups of 4, choose a site around Jennings Hall where you can find arthropod diversity.

- When your group chooses a site, keep in mind materials that might hold arthropod diversity such as leaf litter, pine cones, etc.

Once you have selected your location, you and your lab group should take appropriate field notes via observations on the sheets provided before collecting any substrate for analysis back in the lab.

Once we return to the lab, we will set up your samples for analysis with a Berlese Funnel.

- Your TA will give further directions when we return.
What can we learn about Arthropod diversity from local, urban environments?

Antonio Berlese
1863-1927
Appendix F: Week 2 Slides for Berlese Funnel Exercise

What can we learn about arthropod diversity from local, urban environments?

Directions (Day 2):
Collect your group’s styrofoam cups and divide contents into two petri dishes per group.

Get out dissecting scopes to examine your samples.

Answer your the study questions on your lab sheet and enter specimens found on excel data sheet on TA computer when appropriate.

Wrap-up Lecture at end.

**You lab handout will give you more specific directions.**
Why have the Arthropods been so successful?
Appendix G: Pre-Post Technology Survey

Pre-Post Technology Survey
Questions 19-21 only appear on the post-technology Survey. Additionally, we wrote questions 12-18 with present tense for the pre-technology survey.

1) Please provide your name dot number. This information will be used only to award you bonus points for participating in the survey.
2) Please provide your first initial of your first, middle, and last name with the last two digits of your year of birth (e.g. RTB91 in place of Rob Thomas Buckeye 1991).
3) What is your approximate GPA?
   a. 3.5 – 4.0
   b. 3.0 – 3.49
   c. 2.5 – 2.99
   d. 2.0 – 2.49
   e. Below 2.0
4) What is your gender?
   a. Male
   b. Female
5) What is your race/ethnicity? (drop down menu of choices)
   a. Caucasian (White)
   b. African American
   c. Native American
   d. Asian
   e. Hispanic
   f. Pacific Islander
6) What is your current area of study or major?
7) What is your current rank?
   a. First year
   b. Second year
   c. Third year
   d. Fourth year
   e. Fifth year
   f. Graduate student
   g. Non-degree student
   h. None of the above
8) Check all that apply:
   a. I have an iPod Touch
b. I have an iPhone  

c. I have another type of smartphone  

d. I have an iPad  

e. I have another type of tablet or reader.  

9) Please indicate your level of comfort with PCs:  

a. Very comfortable  

b. Somewhat comfortable  

c. Not comfortable at all  

10) Please indicate your level of comfort with Apple computers:  

a. Very comfortable  

b. Somewhat comfortable  

c. Not comfortable at all  

11) Please indicate your level of comfort with iPads at the end of the semester:  

a. Very comfortable  

b. Somewhat comfortable  

c. Not comfortable at all  

12) I felt that using iPads in class as a digital laboratory notebook was beneficial to my learning.  

a. Strongly Disagree  

b. Disagree  

c. Neutral  

d. Agree  

e. Strongly Agree  

13) I felt that using iPads in class as a sharing device was beneficial to my learning.  

a. Strongly Disagree  

b. Disagree  

c. Neutral  

d. Agree  

e. Strongly Agree  

14) I felt that using iPads increased my engagement in course materials.  

a. Strongly Disagree  

b. Disagree  

c. Neutral  

d. Agree  

e. Strongly Agree  

15) I felt that using iPads allowed me to understand course content in novel ways.  

a. Strongly Disagree  

b. Disagree  

c. Neutral  

d. Agree  

e. Strongly Agree  

16) I felt that using the iPads helped me to organize course content easily.  

a. Strongly Disagree  

b. Disagree  

c. Neutral
d. Agree
e. Strongly Agree

17) I felt that using iPads facilitated group work more easily.
   a. Strongly Disagree
   b. Disagree
   c. Neutral
d. Agree
e. Strongly Agree

18) I feel as though improving my digital literacy is a key component to my education.
   a. Strongly Disagree
   b. Disagree
c. Neutral
d. Agree
e. Strongly Agree

19) Regarding hands-on activities with the iPad, how often would you say that you, personally, used the device?
   a. Never
   b. About 25% of the time
   c. About 50% of the time
d. About 75% of the time
e. Always

20) Please elaborate on three things you liked about using iPads in the classroom/field:

21) Please elaborate on three things you would change about using iPads in the classroom/field:
Appendix H: Gymnosperm Exercise Ohio Plants Version

Gymnosperms, EEOB 2210, Ohio Plants

Goals:
1. To discover the life history and the structures of the life history of various gymnosperms based on observations from the field
2. To differentiate between common genera of conifers

I. Divide into pairs. Pair with another student that is at your table in either lecture or lab. Each pair will be assigned one of the following genera of conifers.
- Pine (Pinus)
- Spruce (Picea)
- White cedar (Thuja)
- Red cedar/Juniper (Juniperus)
- Yew (Taxus)

II. On the iPad provided, you will have 20 minutes to draw, describe and label features of your taxon, including lifecycle characters, and characters that you think define the genus (conserved characters) and distinguish it from other genera. You should document at least the following:
1. The entire plant
2. Branch
3. Close up of leaves
4. Sexual condition of the plant, i.e., monoecious or dioecious
5. Female cones or structures
6. Seeds
7. Male cones, if present
8. Mode of dispersal of seeds
9. Any other characters that distinguish the genus

Both you and your partner should observe all features, but each of you should document half of the observations. Place your initials beside any section that you document.

III. For the next 10 minutes, meet with the other students with your same genus. Share drawings and notes.
Create two lists of characters (include drawings if necessary).
1. Features that describe the lifecycle of your genus
2. Characters that define your genus and distinguish it from other conifers
   • You and your partner should record the lists on your paper.

IV. For the last step, you and your partner will have 10 minutes to compose a narrative about your plant that 1) describes the structures of the life history and outlines the life history, and 2) defines the genus and differentiates it from other genera of conifers, based on characters that you have observed in the field. Reference your drawings.
   1. Your final narratives should be comprehensive enough so that you can teach other students in the class about your findings. You and your partner will be doing this in step V below.
   2. Plan on using props for the presentation, i.e., a tree, cones, seeds, leaves, etc. If you find male cones, please show them to others, but do not pick them.
   3. Your final narratives, pictures and notes will be scanned and posted on Carmen as a study aid for you and your classmates.
   4. Remember that you are responsible for the material that others present and they for yours.

V. You and your partner will have 5 minutes to describe the lifecycle and the distinguishing characters of your genus to your classmates. Divide the presentation between the two of you.
Appendix I: Gymnosperm Exercise Organismal Diversity Version

**Gymnosperms, EEOB 3320, Organismal Diversity**

**Goals:**

1. To discover morphological features of various gymnosperms, including conifers in the Pinophyta and Ginkgo in the Ginkgophyta.
2. To use features of gymnosperms observed in the field to form hypotheses about the lifecycle of the plants.
3. To use features of gymnosperms observed in the field to form hypotheses about the ecology of the plants.

**Note:** Please do not move to the next part of the activity until told to do so, and after the time given for each section.

Label each section distinctly as you progress through the activity.

**Plant Assignments:** Each table group will investigate a given genus of a gymnosperm according the following:

1. Tables 1 & 2: Various species of Pine (*Pinus*)
2. Tables 3 & 5: Various species of Spruce (*Picea*)
3. Tables 6 & 7: Yew (*Taxus*)
4. Tables 8 & 9: White cedar (*Thuja*)
5. Tables 10 & 11: Various species of Red cedar/Juniper (*Juniperus*)
6. Tables 12 & 13: *Ginkgo biloba*

**I.** On the iPads provided, you will have **30 minutes** to draw, describe and label features of your plant, including characters that illustrate its lifecycle and its ecology. You should document **at least** the following:

1. Entire plant
2. Branch
3. Close up of leaves
4. Sexual condition of the plant, i.e., are both male and female on the same plant or on different plants
5. Female structures
6. Male structures
7. Mode of dispersal of seeds
8. Any other characters needed to address the goals above or to address the subjects in part III below

* Each drawing should be numbered, labeled and captioned.

* Each group member should observe all features, and each should document part of the observations.

* Place your initials beside any section that you document.

II. For the next 20 minutes, meet with the other students with your same plant. Share drawings and notes. Create two lists of characters (include drawings if necessary).

1. Features that describe the lifecycle of your plant.
   • Also, label what structure(s) are sporophyte and gametophyte, and where spores and gametes are found

2. Characters that you used to hypothesize the ecology of your plant

III. For the last step, you and your group members will have 30 minutes to compose a narrative about your plant 1) that describes the overall structures of your plant 2) that outlines the lifecycle of your plant, presented in sequential order of events 3) that describes your hypothesis of the ecology of your plant and the features upon which you based the hypothesis. In each case, reference your drawings.

1. Your final narratives should be comprehensive enough so that you can teach other students in the class about your findings. You will be doing this in step IV below.

2. Plan on using props for the presentation, i.e., a tree, cones, seeds, leaves, etc. If you find male cones, please show them to others, but do not pick them.

3. Your assignment will be scanned and posted on Carmen as a study aid for you and your classmates.

4. Remember that you are responsible for the material that others present, and they for yours.

IV. Each group will have 5 minutes to describe the characters, the lifecycle, and the ecology of your plant to your classmates (see below). Each member of your group should give a part of the presentation. Part of your grade for this activity will be based on the completeness of your presentation.
   • You will give your presentation to other groups based on the following clustering: tables 1, 3, 7, 8, 10, 12 and tables 2, 5, 6, 9, 11, 13

* This activity is worth 15 in-class points.
Whitney Cedar (Thuja)
4) monoecious

1) Whole Tree

3) Close up of Leaves

2) Branch

5) Cones

Appendix K: Gymnosperm Exercise iPad Completed Student Sample
Narrative: life cycle and characteristics

Large when full grown, this evergreen is monoecious, meaning it contains both the male and female cones which separate it from other conifers. The male cones are very small and located at the tips of the lateral branches, while the female cones are larger and grow in more apparent clumps on terminal branches. The seeds are produced in the female cones and dispersed mainly by wind and also by water travel. The leaves are alternate fan shaped with scales, like many conifers the bark is shredded and flakes off easily. This species thrives in moist environments.
Appendix L: Chapter 3 Supplementary Materials

Figure L.1. Frequencies of student responses to pre-post technology survey question 3: “What is your approximate GPA?” by students in Ohio Plants.

Figure L.2. Frequencies of student responses to pre-post technology survey question 4: “What is your gender?” by students in Ohio Plants.
Figure L.3. Frequencies of student responses to pre-post technology survey question 7: “What is your current rank?” by students in Ohio Plants.