A Longitudinal Study of iPads on Undergraduate Learning in an Ecology Laboratory

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Abstract: Technology has long been implemented in education and iPads are increasingly used in undergraduate courses. This study was conducted to evaluate the effects of using iPads on undergraduate student learning in the ecology laboratory in 2013-2015. Two sections of the ecology laboratory were studied each year: one group used iPads and the other used conventional paper manual. Pre- and post-quizzes and a post-laboratory survey were conducted to assess student attitudes toward iPad use as well as learning outcomes. The pre- and post-quiz scores didn't show significant differences between the iPad group and the conventional paper group. The survey results indicated students generally had positive attitudes towards using iPads: iPads made labs more interesting and convenient, saved time, and simplified data transfer and processing. Students who used iPads were more likely to recommend their use and embrace new technology. However, the students didn't agree that iPad use encouraged them to learn, promoted participation, or improved knowledge comprehension. We concluded that use of new technology should depend on learning outcomes and instructional strategies, suggested openness to adopt a new technology by both teachers and students and recommended appropriate implementation and clear assessment of using technologies in undergraduate learning.

Keywords: educational technology, iPads, science laboratory, undergraduate education, learning assessment

Introduction

The seven principles of good practice in teaching have been one of the most popular guidelines for teaching and learning in higher education. The principles stipulate that good practice should encourage contact between students and faculty, develop reciprocity and cooperation among students, encourage active learning, provide prompt feedback, emphasize time on task, communicate high expectations, and respect diverse talents and ways of learning (Chickering & Gamson, 1987). These principles have been shown to be effective in undergraduate education since they were first mentioned in publication in late 1980s (Armstrong et al., 2007; Hiltz, 1988; Johnson et al., 1991; Levesque, 2011; Ryu & Zhu, 2021; Uno et al., 2013). For example, collaborative learning, academic learning communities, and use of technologies such as clickers in the classroom have many attributes of the seven principles such as encouraging contact between students and faculty, promoting collaboration among students, and giving prompt feedback. Armstrong et al. (2007) showed that cooperative working among students in small groups improved student outcomes (e.g., the knowledge improvement in course material) in a large biology course. A study on an academic learning community between ecology and statistics courses revealed this high-impact practice improved students' knowledge in statistics and their understanding of ecological problems (Ryu & Zhu, 2021). In another biology course, genetics, students were found to improve problem-solving skills by using clickers and class discussions (Levesque, 2011). Use of technologies like clickers therefore can encourage applications of the seven principles and could promote student learning.

Technology has long been implemented in education (Alavi & Leidner, 2001; Bates & Poole, 2003; Chickering & Erhmann, 1996). Currently students live in a world filled with new and advanced technologies and they embrace the digital technologies in the digital age (Roberts, 2020). Teachers should also embrace new technologies and utilize new methods to teach more effectively and help student learn effectively (Guenther et al., 2021; Menges, 1994). Apple's innovation - iPads offer an exciting platform for teaching and learning in a collaborative and interactive way (Melhuish & Falloon, 2010). The original iPad was released in 2010. Since then, it has become increasingly popular in K-12 and higher education (e.g., Hargis et al., 2014; Hilton, 2018; Moon et al., 2017; Stark, 2012; Tay & Wang, 2016; Ulery et al., 2020; Ward et al., 2013) and was even more widely used during the COVID pandemic (Bursztynsky, 2020).

Many studies have been conducted to use iPads in the lectures of undergraduate courses of various subjects (e.g., human anatomy in Scibora et al., 2018; writing in Sullivan, 2013; and education in Wakefield & Smith, 2012). Wakefield and Smith (2012) found iPads in the multicultural education course helped students improve problem-solving skills compared to the traditional class. Sullivan (2013) indicated iPads reinforced students to guide their writing process and encouraged collaborative working. In contrast, Scibora et al. (2018) studied iPad use in human anatomy course and reported the iPad group had lower attainment of course objectives and less class engagement. However overwhelming studies on iPad use demonstrated positive effects on undergraduate teaching and learning (Cavanaugh et al., 2013; Hargis et al., 2014). Compared to the lectures, iPad use in the science laboratories were studied less frequently and the results were mixed. Eid and Al-Zhuhair (2015) studied iPad use in a general chemistry laboratory and found students using iPads were more satisfied with the course although iPads did not improve the students' overall quantitative performance. Chakraborty and Cooperstein (2017) investigated the use of iPad in the anatomy and physiology laboratory for 300 students and reported that students improved their grades and felt they learned more content.

The purpose of this study was to evaluate the effects of a relatively new technology, iPads, on undergraduate student learning in an ecology lab (2013-2015). Integrating iPads in teaching should be welcomed and appreciated by students because they have grown up in the age with advanced technologies and have been using new technologies. The use of iPads will make them feel connected to the real world and become more interested in the subject (Melhuish & Falloon, 2010). Therefore, they will be more likely to enjoy their learning experience and improve learning. More importantly, using iPads will develop cooperation among students, promote greater participation, encourage active learning, and provide instant feedback, thereby promoting effective learning (Chickering & Erhmann, 1996). Use of iPads in the laboratories is expected to save students time on data transfer and processing. The students will therefore have more time to reflect upon why they conducted the particular laboratory, which will reinforce the concepts and knowledge learned in the lecture, and the teachers can devote more class time to helping them do so. Additionally, students can use iPads to take photos in the field to aid further comprehension of environmental problems and preparation for their lab reports. Consequently, it is expected that using iPads will enhance collaboration among students, encourage active learning, and increase time efficiency, which are three important principles of best teaching practices (Chickering & Gamson, 1987).

Methods

Ecology course

The iPads (the 4th generation released in November 2012) were incorporated as a new educational technology into a biological science lab course, BIO260W ecology in 2013-2015, to evaluate their effects on undergraduate student learning. BIO260W is required for all students majoring in biology (both B.A. and B.S. degrees) and is offered only in the fall semester because the weather conditions during early spring in the Northeast U.S. makes it difficult to collect ecological data outside. The course includes two 75-minute lectures and one 2.5-hour laboratory each week. The approximately 25-40 students attend the same lecture section and break into two or three lab sections at different times, each of which is enrolled by 10-22 students. Students in this course are a mix of sophomores, juniors, and seniors with sophomores typically representing the largest percentage (49.2%, 38.7%, and 64.9% in 2013, 2014, and 2015 respectively). They voluntarily enrolled in the sections based on their own class schedules.

The studied ecology laboratory

The selected experiment in the ecology laboratory for testing the iPad use was "Dispersion of Lawn Plants". Distribution pattern is one part of population studies in ecology, and it is impacted by the organisms and the environment. The goal for this experiment was to ask students to collect data in order to quantify the distribution pattern, identify the three types of patterns, and create a histogram to demonstrate data. Specifically, students form a group of 3-4 persons to use one regular adult-size hula hoop as a small sampling quadrat and randomly throw the quadrat on the lawn on the university campus to count how many individuals of broadleaf plantain Plantago major are in the quadrat. They also need to record the growth environment for those plants and repeat the procedure 20 times. In addition, they use three hula hoops together as a big sampling quadrat and repeat the procedure another 20 times. After collecting the two sets of data, students process the data using statistics to calculate variance and mean. Then they apply the index of dispersion - variance/mean ratio to quantify the distribution pattern. When the ratio is approximately 1, the plant population distribution pattern is random; when it is less than 1, the pattern is regular (also called even distribution); and when it is greater than 1, the pattern is clustered (also called aggregated distribution). Students then compare the two sets of data to see whether the size of sampling units makes a difference. Finally, students use EXCEL to create of a histogram for one set of data. The procedure of how to create a histogram is introduced in the lecture before the lab.

Use of iPads and Institution Review

In the studied period of 2013-2015, there were two sections each year in the ecology laboratory. One section was randomly selected to be the control group and the other group was selected to be the treatment. In the control group (paper group), students carried the traditional laboratory manual and pen to the lawn to conduct the experiment, recorded data on paper, and brought data back to the lab to share with partners; then individually they input data into EXCEL and analyzed data. In the treatment group (iPad group), students were given instructions on how to use the iPads to record and transfer data. They took a picture of instruction in the laboratory manual, carried iPad to conduct experiment, and record data; after coming back to laboratory, they emailed data to each partner and individually analyzed data.

This study has been approved by the Human Subjects Committee at the University of Hartford according to conditions set forth in federal regulation 45 CFR 46.101(b) and was determined to be exempt from further committee review. All students were given an informed consent form to review and sign. This form summarized the purpose of the study, indicated that there were no known risks or benefits, and informed them that they could withdraw from the study at any time without penalty.

Assessments using pre- and post-quiz scores and a post-survey

To assess whether the new technology of iPads aided student learning in the laboratory, two types of assessments were used. A quiz (total 10 points) was taken by both groups of students (using iPads and paper manual) immediately before introducing this experiment (pre-quiz, see Appendix I) and another was taken one week after this experiment (post-quiz). Both quizzes had the same questions and were not previously announced. The quizzes were collected, coded, and mixed together by Dr. Levesque and were graded blindly by Dr. Zhu at the same time to avoid bias.

A post-experiment survey was also given to students to evaluate the effects of technology in education (Bangert, 2004); it consisted of 10 ranking scale statements and one open-end question about opinions of using iPad in this experiment. The 10 statements included:

> S1. The iPad use makes the laboratory more interesting/fun; S2. The iPad use encourages me to learnin this laboratory; S3. The iPad use makes the laboratory more convenient (e.g., without carrying a laboratory manual); S4. The iPad use saves my time in the laboratory; S5. The iPad use makes it easy to record, transfer, and share data; S6. The iPad use makes it easy to process the data or create graphs; S7. The iPad use encourages my participation and interaction with group members; S8. The iPad use helps me learn the contents better; S9. I recommend using iPad in the laboratory

when possible; S10. I like new technology to be used in the laboratory in general; Students were asked to rate the statements on a scale of 1-10 where 1 is "strongly disagree" and 10 is "strongly agree" for the statements S1-S10. Students who didn't use iPads in the experiment were asked to complete the survey as if they had used the device. The open-ended question in the survey was: What are your other comments (what aspects you like or what aspects you don't like)?

Statistical analyses

The Shapiro-Wilks test on assumptions of normality and the Levene's test on homogeneity of variance were conducted before data analysis (Allen et al., 2014). Results showed all data met those assumptions with significance level greater than 0.05. We then used Mixed-ANOVA to compare the quiz scores between the iPad and paper groups in both pre- and post-quizzes (Ryu & Zhu, 2021). There were three variables: 1) the dependent variable was quiz score; 2) the between-subjects factor was group, which had two categories: iPad and paper; and 3) the within-subjects factor was time, which also had two categories: pre- and post-quizzes. Results of η^2 (Eta squared) were reported to show effective size. Values of 0.01, 0.06 and 0.14 were considered small, median and large effective size (Schäfer & Schwarz, 2019; Ryu & Zhu, 2021). ANOVA was used to compare the quiz scores among groups in different studied time periods (Kuehl, 2000). Multivariate analysis of variance (MANOVA) was used to compare the post-survey results in S1-S10 for the two groups (iPad vs. paper) and Tukey HSD for post hoc tests was used to compare groups in each question in the survey (Cohen, 1988). All statistical analyses were conducted using IBM SPSS Statistics26 (Allen et al., 2014).

Results

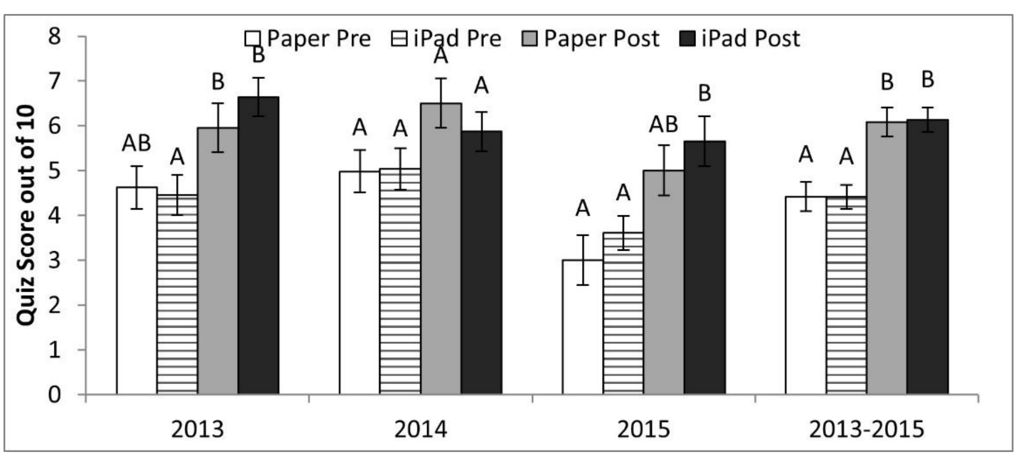
Assessment from pre- and post-quiz scores

There were 90 total students who participated in pre- and post-quizzes in 2013-2015 (9-16 each year in the paper group and 13-21 each year in the iPad group, Table 1). The pre- and post-quiz scores didn't show significant differences between the iPad group and the conventional paper group in each year (Figure 1; all $p>0.05$; all effective size $\eta^2 <0.01$ except $\eta^2=0.05$ in 2015, see Table 1). When data of three years were combined, the result was the same: there were no significant differences in either the pre- or post-scores between the two groups. However, there was a significant time effect when pre- and post-scores were compared (for year 2013, 2014, 2015, and 2013-2015, all $p<0.01$; all $\eta^2>0.30$, see Table 1) and it showed students in both groups consistently increased in post-quiz scores (Figure 1). The trends were slightly different in the three years studied. In 2013, the pre-quiz score for the iPad group was 4.45 ± 0.45 (mean ± SE) out of 10, which was not significantly different from 4.62 ± 0.48 in the paper group. Students in the iPad group increased 49.2% in the post-quiz score to 6.64 ± 0.43 whereas those in the paper group increased 28.7% to 5.95±0.54 although the post-quiz scores didn't differ between the two groups. In 2014, the increases of scores were 16.5% in the iPad group and 30.6% in the paper group whereas in 2015 the increases were 66.7% and 56.7% respectively. When all the three years combined, the increases were nearly the same (37.5% vs. 38.8%), which again presented no differences between the iPad group and the paper group.

Assessment from the survey

There were 41 total surveys (10-16 each year) collected in the paper group and 50 total in the iPad group (13-21 each year, Table 1). The results of S1 to S10 statements in the survey between the two groups showed significant differences in levels of their opinions (i.e., the scaling value, Figure 2). The two groups differed in 2013 (df=10, F=2.827, p=0.016), 2014 (df=10, F=2.938, p=0.019), and 2013-2015 (df=10, F=3.334, p=0.001) whereas 2015 revealed no differences (df=10, F=2.476, p=0.07) However, the comparisons between groups varied each year. In 2013, the group using iPads had more positive views (5.5 is the value for a neutral opinion; positive view is >5.5 and negative view is <5.5) on the use of iPads than the group who used paper manual. There was a consistent trend that the average score for each of the 10 statements was lower in the conventional paper group than those in the iPad group (Figure 2A). Scores in five statements were significantly different between the two groups: S3 iPads make the laboratory more convenient; S7 iPads encourage participation and interaction; S8 iPads help learn better; S9 I recommend use of iPads in the laboratory; and S10 I like the new technology used in the laboratory in general (all p<0.05).

Figure 1. Pre- and Post-Quiz scores for two groups of students using traditional paper manuals and using iPads in the ecology laboratory experiment.



Data were shown as mean ± SE. Different letters above the columns denote significance at the level α=0.05.

Table 1. Sample size for quiz and survey for two groups of students using traditional paper manuals and using iPads in the ecology laboratory experiment and effective size η² in quiz

	Year	2013	2014	2015	2013-2015
Quiz sample size	Paper	16	14	9	39
	iPad	21	17	13	51
Survey sample size	Paper	16	15	10	41
	iPad	21	16	13	50
η² for group in Quiz		<0.001	0.007	0.048	<0.001
η² for time in Quiz		0.378	0.382	0.307	0.340

Among the five, four statements (S3 and S7-9) were shown opposite views (the iPad group >5.5 and the paper group <5.5). In 2014, no clear trend was observed. Four statements S5-S8 showed higher average scores in the paper group than the iPad group although they were not significantly different (Figure 2B). In 2015, there was no clear trend either but all the views were positive (>5.5) in both groups (Figure 2C). When data of 2013-2015 were combined and compared, they revealed significant differences in three statements between two groups (the iPad group had higher values and more positive views): S3 iPads make the laboratory more convenient; S9 I recommend use of iPads in the laboratory; and S10 I like new technology to be used in the laboratory in general (Figure 2D).

The survey data also demonstrated consistently low scores in three statements in each year: S2 The iPad use encourages me to learn in this laboratory, S7 iPads encourage participation and interaction, and S8 iPads help learn better. In the combined 2013-2015 data, both groups presented relatively neutral views on S7 (5.90±0.39 in the iPad group vs. 5.56±0.51 in the paper group). Both groups had negative views on S2 (5.42±0.38 vs. 5.12±0.42) and S8 (5.20±0.38 vs. 4.49±0.41, the lowest scores).

Summary of student comments

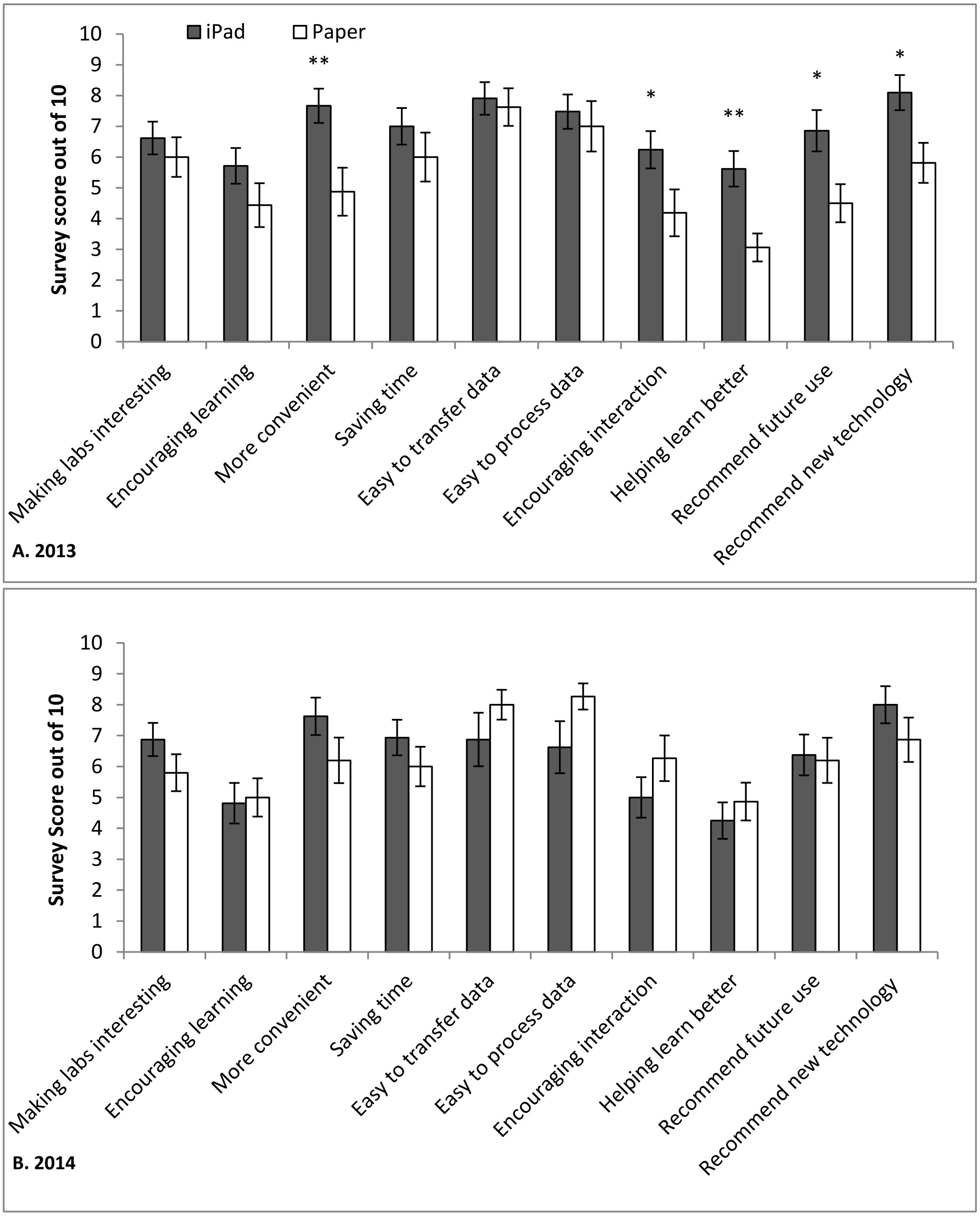
A total of 39 student comments were provided by students in the three-year study period (17 in 2013, 16 in 2014, and 6 in 2015; Appendix II). The iPad groups had 7, 12, and 5 comments and the paper groups had 10, 4, and 1 comments in 2013, 2014, and 2015 respectively. In 2013, 3 comments in the iPad group stated iPad use was helpful and made it easier whereas 4 comments talked about the difficulty of transferring data from iPads to individual students. In the paper group, 2 students thought it would be good, 6 were worried about the iPad use (e.g., distracting, lack of knowledge to use the device, and damage), one was neutral, and the other one didn't show his/her opinion on iPad use. In 2014, 9 students in the iPad group thought iPad use was good (convenient and easy to record and transfer data), 2 complained about data transfer, and one recommended use of iPad mini because iPad was heavy. In the paper group, one supported the idea of iPad use, one had a neutral view, one worried lack of knowledge to use, and the other one had a mixed view - it was good, but it might be a distraction and hinder personal interactions. In 2015, 4 out of 5 comments in the iPad group had positive views on iPad use and one student preferred paper manual. In the paper group, the only comment expressed concern about whether the iPad could function smoothly.

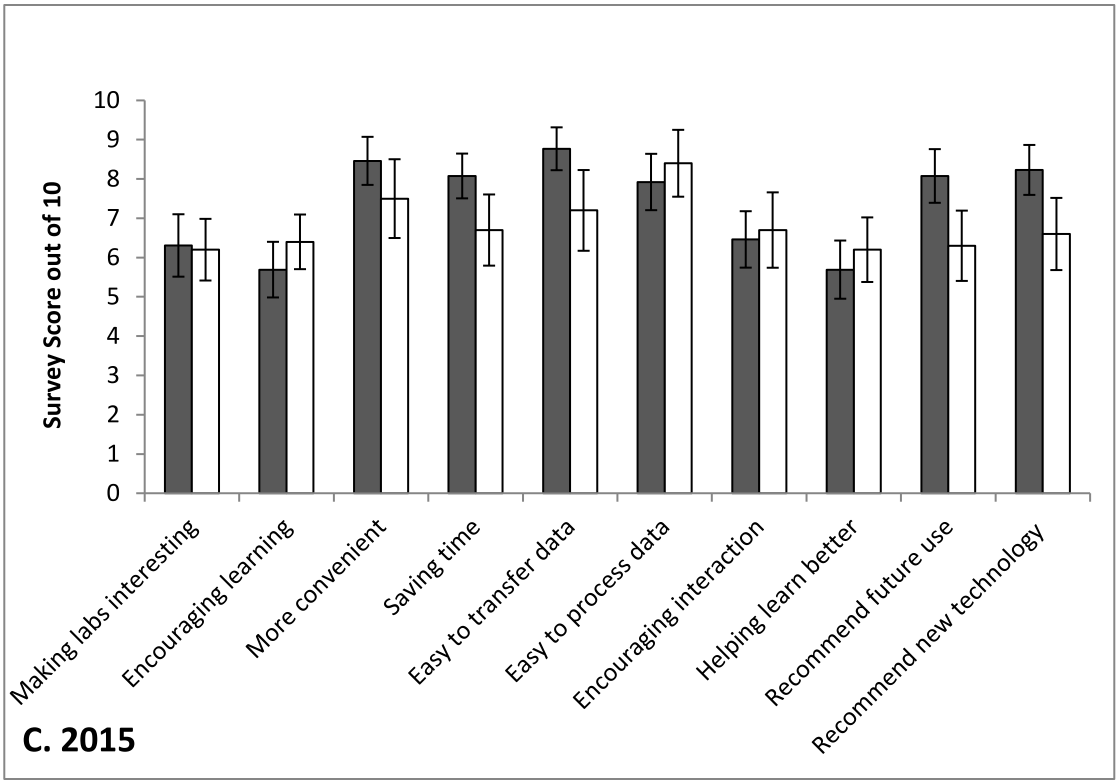
Discussion

Our study demonstrated students in both groups had positive views on iPads (score>5.5): making labs more interesting, more convenient, saving time, easy to transfer data, and easy to process data. However, the students didn't think use of iPads encouraged them to learn and participate or improve learning outcomes. These latter attitude results were contradictory to our expectations and many other studies that demonstrated technology like iPads encouraged learning and promoted collaborations in undergraduate education (Bates & Poole, 2003; Melhuish & Falloon, 2010). They were also not consistent with studies in several science laboratories. For example, in the anatomy and physiology laboratory (Chakraborty & Cooperstein, 2017), students felt more positively about learning using iPads and improved their grades; in a chemistry laboratory (Eid & Al-Zhuhair, 2015), it was also found that students felt more satisfied with learning content with iPads despite no improvement in grades. The quantitative data from the pre- and post-quiz scores also confirmed that iPads didn't help students gain more knowledge in the ecology laboratory. Different results in attitudes and quantitative data might be due to the length of use of iPads. In the other studies, iPads were used for a semester or longer whereas our study only used iPads once in one experiment. More use of iPads would help students get more familiar with the technology and application of iPads in the whole laboratory course might produce different results. Another reason might be that iPads were more like a tool for recording and transferring data in this study instead of a technology of learning in the whole semester.

The trend of changes in views toward iPads from 2013 to 2015 indicated that students were reluctant to changes in learning and familiarity of the technology could ease the reluctance. There were five opposite statements (iPad group >5.5) in 2013, only one in 2014 (paper group >5.5), and zero in 2015 (all positive views). In 2015, iPads were ubiquitous and considered a common device in the society. Therefore, student attitudes changed due to familiarity. However, in 2013 (only three years after the first iPad release), students who didn't use iPads had strong reservations about this technology whereas those using iPads welcomed it despite the fact that a number of students in the iPad groups had technical difficulties (which were reflected in student comments). By viewing the comments in the survey

Figure 2. Survey ranking scores of ten categories for two groups of students using traditional paper manuals and using iPads after the ecology laboratory experiment was completed. A. data from Fall 2013; B. data from Fall 2014; C. data from Fall 2015; and D. combined data for 2013-2015. Data were shown as mean ± SE. * indicates significance at the level α=0.05 and ** indicates significance at the level α=0.01.

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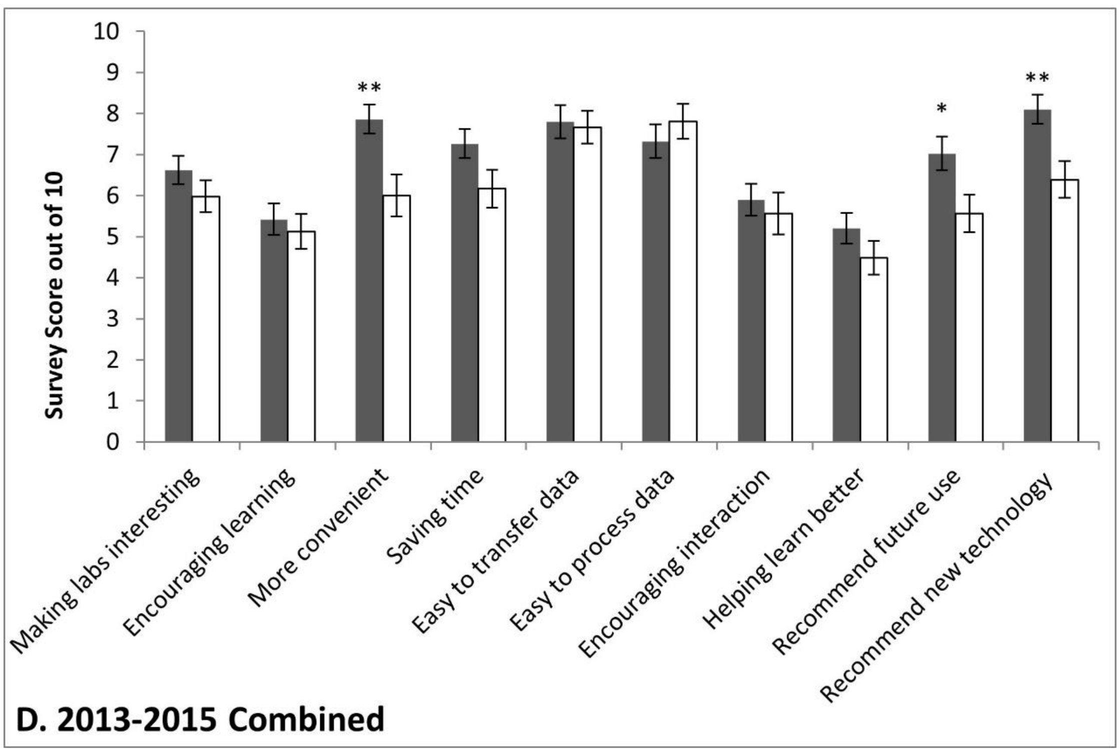
Survey Score out of 10
Making labs interesting
Encouraging learning
More convenient
Saving time
Easy to transfer data
Easy to process data
Encouraging interaction
Helping learn better
Recommend future use
Recommend new technology
C. 2015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Making labs interesting
Encouraging learning
More convenient
Saving time
Easy to transfer data
Easy to process data
Encouraging interaction
Helping learn better
Recommend future use
Recommend new technology
D. 2013-2015 Combined

from students who did not use iPads, we found the negative attitudes might be due to the following reasons: some were afraid of using iPads due to lack of knowledge; some worried that using them can be a distraction because students may be interested in the technology itself instead of the laboratory; some thought iPads might break or could not function well; and some just didn't like Apple products. These concerns were reasonable and therefore it was not surprising to see students were afraid of changes in learning at the beginning. However, they may change their view if they are provided with appropriate instructions and have an opportunity to try using the new technology as shown in this study: students who used iPads were more likely to recommend their use and embrace the use of new technology (e.g., King et al., 2014).

There are many barriers to adopt new technology in education and attitudes of teachers and students are important factors (Rogers, 2000). To foster positive attitudes and clear the misperceptions of new technology, structured guidance and positive teachers' attitudes are highly recommended. Christensen (2002) revealed that positive teacher attitudes toward information technology foster positive attitudes in their students. Other studies also reported teacher's openness to change may influence the technology integration and the technology impact on content acquisition (Baylor & Ritchie, 2002). Therefore, teachers should be open for change and have positive attitudes toward integration of new technology in undergraduate education. Following these, students can have positive attitudes toward new technology, which in turn may improve learning. This is particularly important for current undergraduates, who are considered as the Net generation. They expect any technology used in education should be customized for their needs and should not require them to change (Roberts, 2020).

Adopting and applying technology is not guaranteed to fulfill all the learning outcomes. It is highly recommended an appropriate implementation should be executed and a clear assessment about the advantages and limitations of new technology should be conducted after the experimentation or implementation of new technology (Melhuish & Falloon, 2010). Not a single new technology will promote every aspect of the learning outcomes (e.g., the seven principles of good practice). Adoption and choice of new technology should depend on learning outcomes and instructional strategies (Chickering & Erhmann, 1996). For any given instructional strategy, some technologies are better than others. No matter what technology is used, it is important to utilize consistent instructional methods in undergraduate education (Scibora et al., 2018).

There were several limitations in this study. Like many studies, the sample size was relatively small in this study (e.g., Ryu & Zhu, 2021; Wakefield & Smith, 2012). Larger sample size would make data more powerful and results more convincing. Also, the study lasted three years (which was better than a one-time study) but the results varied each year. A longer term would make it easier to interpret data. The variability from year to year could be due to familiarity of iPads by students as explained before. It could also be due to other reasons such as the academic abilities of students each year, different academic years (sophomore through senior), and different levels of knowledge and accessibility to technology among students. The average GPAs for the three years of the study (2013, 2014, and 2015), determined by recording the GPA of each student as of the semester prior to entering the ecology course, were 3.15, 2.87, and 2.79 in the iPad sections, respectively, while the paper sections had GPAs of 3.22, 3.21, and 3.25, respectively. It was significantly different in two groups in 2015 and 2013-2015, reflecting the differences in student academic abilities. Also, it was true that sophomores represented the largest group, but the percentages were different (49.2%, 38.7%, and 64.9% in 2013, 2014, and 2015 respectively), meaning the composition of sophomore, juniors, and seniors were different each year. It is possible that differences in student academic years and/or academic abilities can impact student attitudes about using new technologies as well as the learning outcomes associated with the technologies. In addition, the iPad application was only used in one laboratory experiment; more repeated uses of iPads in the whole course would make it easier to compare with other studies. Lastly more assessments in addition to pre- and post-quizzes and a post-survey might provide more accurate and holistic views (Ryu & Zhu, 2021). Despite these limitations, our study added another case study of using iPads in a science laboratory and provided useful information about technology use in higher education such as calling for openness to adopt a new technology by teachers, reducing student reluctance of using new technology by providing guidance and more practices, and recommendations of various assessments.

Conclusions

This study revealed students generally had positive attitudes towards using iPads in an ecology laboratory: they made labs more interesting and convenient, saved time, and simplified data transfer and processing. Students who used iPads were more likely to recommend their use and have positive attitude towards new technology use in the laboratory than students who did not. However, the students didn't agree that use of iPads encouraged them to learn and participate or improve learning outcomes. This study also showed no improvement in the knowledge comprehension for students. Further investigation is necessary to evaluate whether the new technology such as iPads can promote effective teaching and learning in undergraduate science laboratory courses. Adoption of new technology should depend on learning outcomes and instructional strategies. It is highly recommended that appropriate implementation and use of technologies should be executed and clear assessments about the advantages and limitations of new technology should be conducted.

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The authors declare no conflict of interest.

Author contributions

Bin Zhu: Conceptualization; Formal analysis; Investigation; Validation; Writing-original draft; Writing-review & editing. Aime A. Levesque: Conceptualization; Investigation; Validation; Writing-review & editing.

Institutional Review Board

This project was approved by the Human Subject Committee at the University of Hartford and was exempt for further review.

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