Bring Your Own Device Initiative to Improve Engagement and Performance in Human Anatomy and Physiology I and II Laboratories

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Bring Your Own Device Initiative to Improve Engagement and Performance in Human Anatomy and Physiology I and II Laboratories

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Abstract
In an informal survey, just 4.93% (2014) and 6% (2015) of Human Anatomy and Physiology students stated that their favorite lab activity was using a microscope. Additionally, performance on lab practical microscopy questions was low with the average percent correct between 31.85% and 41.94%. To increase student interest, engagement and performance, we purchased microscope adapters that allow students to take photomicrographs with their smartphones. Likert surveys were used to assess student engagement, and the percent of correct answers on histology questions on lab practicals. Comparisons were made between semesters where adapters were used and not used. Results show that lab practical scores were higher in semesters where microscope adapters were used compared to semesters where they were not used, but the increase in student performance was not significant. The use of smartphones along with microscope adapters has the potential to improve student engagement, but the role that smartphones play in student performance is unclear. doi: 10.21692/haps.2018.004

Key words: smartphones, BYOD, histology, laboratory education

Introduction
Smartphones are mobile phones that have advanced connectivity options such as Wi-Fi and web-browsing capability as well as sophisticated computing abilities and built-in applications (Soikkeli *et al.* 2013, Chan *et al.* 2014). Ownership of smartphones among adults has increased over the past years (Falaki *et al.* 2010, Soikkeli *et al.* 2013) with ownership rates rising from 35% to 68% between 2011 and 2015 (Anderson 2015). Smartphones are convenient technological tools for learning in terms of portability, affordability, accessibility, operability, and applicability (Kafyulilo 2012). Through "Bring Your Own Device" (BYOD) initiatives, educators are starting to incorporate students' mobile technology including smartphones into the classroom curriculum (Kiger and Herro 2015). However, little research has been done to examine how the utilization of smartphones in the laboratory impacts learning outcomes, particularly in a science laboratory.

The increased ubiquity of mobile devices such as smartphones on college campuses allows for new instructional strategies for higher education students (Gikas and Grant 2013), but their implementation into academic institutions for learning purposes remains an ongoing debate. BYOD appears to be gaining acceptance in K-12 school districts (Burns-Sardone 2014), but it is still not universally supported. It has been found that there is a significant difference between the age of the instructor and support of using mobile phones in the classroom, with those over age 50 being less accepting than those who are aged 33-49 or are less than 32 years of age (O'Bannon and Thomas 2014). Instructors may also be hesitant to incorporate technology into their classrooms because, according to Gikas and Grant (2013), there is little research regarding how these tools are being used for teaching and learning purposes, especially by university students.

Using microscopes to study biological tissues (i.e. histology) is a particularly challenging skill for students in Human Anatomy and Physiology at the University of Mississippi. In the fall of 2014, 59.18% of students responding to an informal, opinion survey stated that the most difficult part of learning tissues was remembering what the tissues looked like. In additional informal surveys, the percentage of students who stated that their favorite lab activity was using the microscopes was 4.93% in 2014 and 6% in 2015. In addition, performance on lab practical questions involving the identification of specimens under a microscope is poor, with the average percent correct as low as 31.85% and no higher than 41.94%. These numbers are troubling because Human Anatomy and Physiology I and II are required courses for students desiring entry into many allied health professions (e.g. nursing, occupational therapist, physician assistant, etc.) where knowledge of tissues, obtaining samples for biopsy, and interpreting microscopic specimens are critical to job performance. Nivala *et al.* (2013) found that students' prior histological knowledge is a predictor of medical student performance in diagnostic pathology, confirming the value of having a strong background in the basic medical sciences.

According to Morrison and Gardner (2015), the first time a mobile phone was used to capture a microscopic image occurred in 2009. Students currently use their mobile phones

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to try to take pictures of microscope slides by holding their phone's camera lens over the ocular lens of the microscope. It is difficult to get the focal point of the phone's camera lens and the ocular lens of the microscope to properly align with this technique however, and according to Morrison and Gardner (2015), it requires "practice, patience, and a steady hand." In 2012 companies started manufacturing accessories such as microscope adapters which attach smartphones to a microscope allowing students to take high quality pictures through the microscope by aligning focal points of both lenses (Morrison and Gardner 2015).

In recent years, United States governmental agencies have called for the transformation of undergraduate STEM (science, technology, engineering, and mathematics) courses to include active learning in the classroom (Shaffer 2016). In addition, the Vision and Change report from the American Association for the Advancement of Science (2011) suggests that active learning methods in the classroom should be implemented to increase student performance in undergraduate life science courses. High structure course methods involving active learning have been shown to increase student engagement and performance (Shaffer 2016) and using smartphones in the laboratory along with microscope adapters may allow for the same effects by increasing self-motivation. Sturges *et al.* (2016) have shown a significant relationship between student GPA, the number of hours of studying students reported, overall self-reported motivation, and academic performance in undergraduate Human Anatomy and Physiology courses.

Use of mobile devices in the laboratory could improve student engagement within the laboratory, expand the learning environment, and promote the productiveness of faculty and students (Dahlstrom 2013). Allowing students to photograph microscope slides with their phones may enhance student confidence that they have the information they need to study for the histology questions on exams. Student confidence may increase the amount of self-efficacy students have when it comes to answering those questions. Solberg (2012) showed that self-efficacy could translate into improved performance and learning outcomes because of higher confidence levels. Additionally, the convenience of having their own photomicrographs on their device may motivate students and encourage them to spend more time studying. The convenience and flexibility of smartphones provide opportunities for students to collaborate with classmates and access course material regardless of their location (Traxler 2007, Kafyulilo 2012, Gikas and Grant 2013). Students who spend more time studying material that will be on the lab practical do better on lab practical exams (Cogdell *et al.* 2012).

Some concerns associated with allowing students to use their mobile phones in the classroom include device theft, security, equity, distractions, and inappropriate use of the device (Hartnell-Young *et al.* 2008, Kafyulilo 2012, Thomas *et al.* 2014, Kiger and Herro 2015). These concerns, however, do not pertain to college students who are the focus of this study. Kafyulilo (2012) also stated that effective ways to "subdue the negatives and promote the positives" of smartphones should be found because the benefits of using smartphones in the classroom seem to outweigh the drawbacks.
When implementing BYOD policies, the ease of using smartphones for laboratory teaching purposes does not necessarily make them appropriate and effective, pedagogically (referring to the method and practice of teaching children; Kiger and Herro, 2015) or andragogically (referring to the method and practice of teaching adult learners.

The purpose of our study is to provide an evidence-based resource for educators considering implementing the use of student smartphones and mobile devices in the laboratory. Our hypothesis is that use of microscope adapters with student smartphones will improve student engagement in the laboratory and performance on histology-based questions on lab practicals. This study will serve as a resource in the debate of curricular incorporation of smartphones and will help inform educators, schools, and universities about the effects of incorporating smartphones into the laboratory for learning purposes.

Materials and Methods

Five hundred and fifty-six students enrolled in Human Anatomy and Physiology I (BISC 206) and II (BISC 207) at the University of Mississippi were recruited to participate in this study. Anatomy and Physiology I and II represent a two-semester course sequence in which students must successfully complete Anatomy and Physiology I (with a C or better) before taking Anatomy and Physiology II. At the University of Mississippi, Anatomy and Physiology I is only offered in the fall semesters with approximately 390 students enrolled in one lecture section and 13 lab sections. Anatomy and Physiology II is only offered in the spring semesters with approximately 250 students enrolled in one lecture section and 9-10 lab sections. All participants were typical undergraduate college students ranging between the ages of 18 and 23 and varying in race and gender.

This study was incorporated into the histological portions of the laboratory sessions, but students were informed that involvement in this study was optional. Our protocol was approved as Exempt under 45 CFR 46.101(b) (#1 and 2) by the University of Mississippi Institutional Review Board (Protocol #16x-162). Students were not compensated in any way or awarded course credit for participation in the experiment. It is highly unlikely that any of these students were repeats since students in Anatomy and Physiology II in Spring 2016 had already passed Anatomy and Physiology I, and would therefore not enroll in Anatomy and Physiology I in Fall 2016.

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Sixteen universal microscope adapters [Carson Hookupz™ (IS-100) Universal Smartphone Optics Adapter from Carson Optics] were purchased for this study. These adapters allow students to take high quality pictures through the microscope with their mobile devices in the laboratory by aligning the focal points of the smartphone's camera lens with the microscope's ocular lens. This adapter was designed to fit most smartphones with or without phone cases including all iPhone models (except the iPhone 6 Plus), all Samsung Galaxy models, HTC One, HTC Evo 4G/4G LTE, LG G2, Motorola Moto X/G, Droid Razor, etc. (Carson Optics, 2016). With an outer eyepiece diameter of 20-58mm, this adapter was designed to fit 99% of all optics and is compatible with most microscopes, including slit lamp microscopes, binoculars, monoculars, endoscopes, etc. (Carson Optics, 2016). Other adapters were available at the time of purchase, but they were unable to fit multiple types and sizes of smartphones. For example, the Magnifi™ is an iPhone photoadapter case that was made to be compatible with only iPhones 4, 4s, 5, 5s, or SE, and it requires the user to remove their phone case to fit the adapter on the iPhone (Magnifi, 2016). Since completing this study, Carson Optical has developed the HookUpz™ 2.0 Universal smart phone optical adapter (IS-200) as well as adapters made to fit specific iPhone models (Carson Optics, 2017).

The microscope adapters were used in the laboratory during the Spring 2016 (Anatomy and Physiology II students) and Fall 2016 semesters (Anatomy and Physiology I students). Students were able to digitally capture microscopic images they found interesting as well as tissues and structures they needed to know and identify on the lab practical. These pictures could then be used by the student as a resource for study or shared with classmates via text message, social media, or email.

Two surveys were given to students each semester to assess the students' level of interest and engagement with microscopy and tissue examination both before and after the use of the microscope adapters along with their smartphones. Survey questions were predominantly Likert-style and asked participants to give a rating from strongly agree to strongly disagree in response to each statement. The first survey was administered to the students in the laboratory at the beginning of the semester. Students were then given instructions on how to use the microscope adapter, how to hook up the smartphone to the microscope adapter, and how to hook up the adapter to the microscope lens. A short video from the Carson website showing how to use the microscope adapter was also shown to the students (CarsonOptical, 2014). Refresher instructions were given throughout the course as needed. Students used their smartphones along with the microscope adapters to take pictures of specimens under the microscope in several laboratory exercises throughout the semester. The second survey was given to students at the end of the semester after their last laboratory session involving the use of the microscope adapters along with their smartphones.

Two, 50-question, hands-on lab practicals are given during Anatomy and Physiology I and Anatomy and Physiology II. The lab practicals contained one to ten histology-based questions that involved identifying anatomical structures through a microscope. Students were required to write their answers down on a blank answer sheet in a free response format. The teaching assistants of each laboratory then graded these questions manually.

Aggregate performance (i.e. percent correct) on each histology question was calculated by dividing the number of correct responses for each histological lab practical question by the total number of student responses per question. For Anatomy and Physiology I, performance on the histology-based questions from each of the two lab practicals was compared between the Fall 2015 semester (microscope adapters were not used) and the Fall 2016 semester (microscope adapters were used). For Anatomy and Physiology II, performance was compared between the Spring 2015 semester (microscope adapters were not used) and the Spring 2016 semester (microscope adapters were used).

Performance data were analyzed using two-tailed t-tests assuming unequal variances. Chi-square analyses were performed for Likert-style and categorical survey questions. To examine differences in survey responses between low, medium, and high users of adaptors, a one-way analysis of variance (ANOVA) tests were performed for questions asking the students to respond with a ranked rating from 1-10. The level of significance was set at alpha = 0.05 for all analyses. Statistical tests were performed using Microsoft Excel and StatPlus.

Results

Student Profiles

Enrollment data and survey responses show that most students enrolled in Human Anatomy and Physiology I and II were pursuing a career in an allied health profession (e.g. nursing, physical therapy, occupational therapy, dietetics, or physician assistant), with the most common majors being exercise science, a (2+2) or (3+1) allied health program such as nursing or occupational therapy, and dietetics and nutrition. All but two students owned some type of smartphone that allowed them to take pictures, and most students (257) reported having 16 gigabytes (GB) of memory available on their smartphone.

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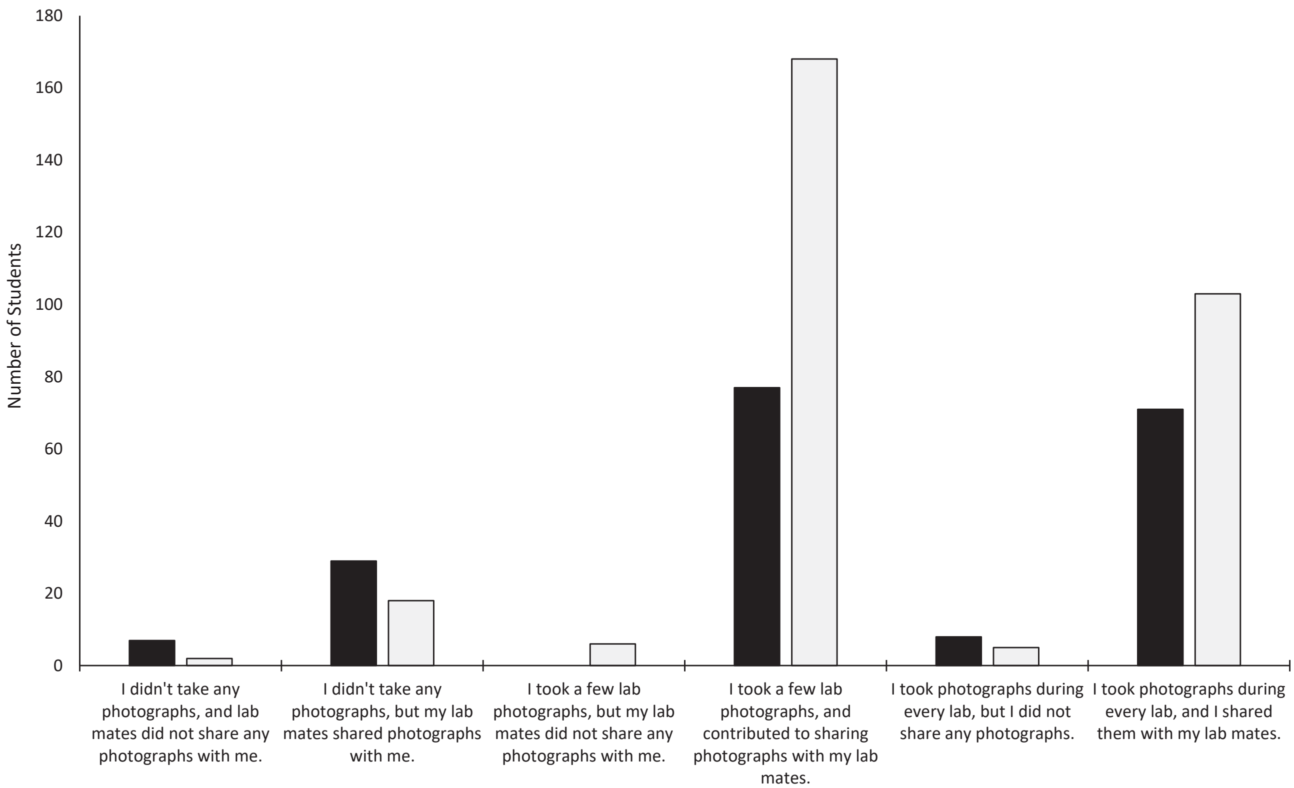

Figure 1. Human Anatomy and Physiology I (black bars) and II (gray bars) student responses regarding how they used the microscope adapters within their lab group.

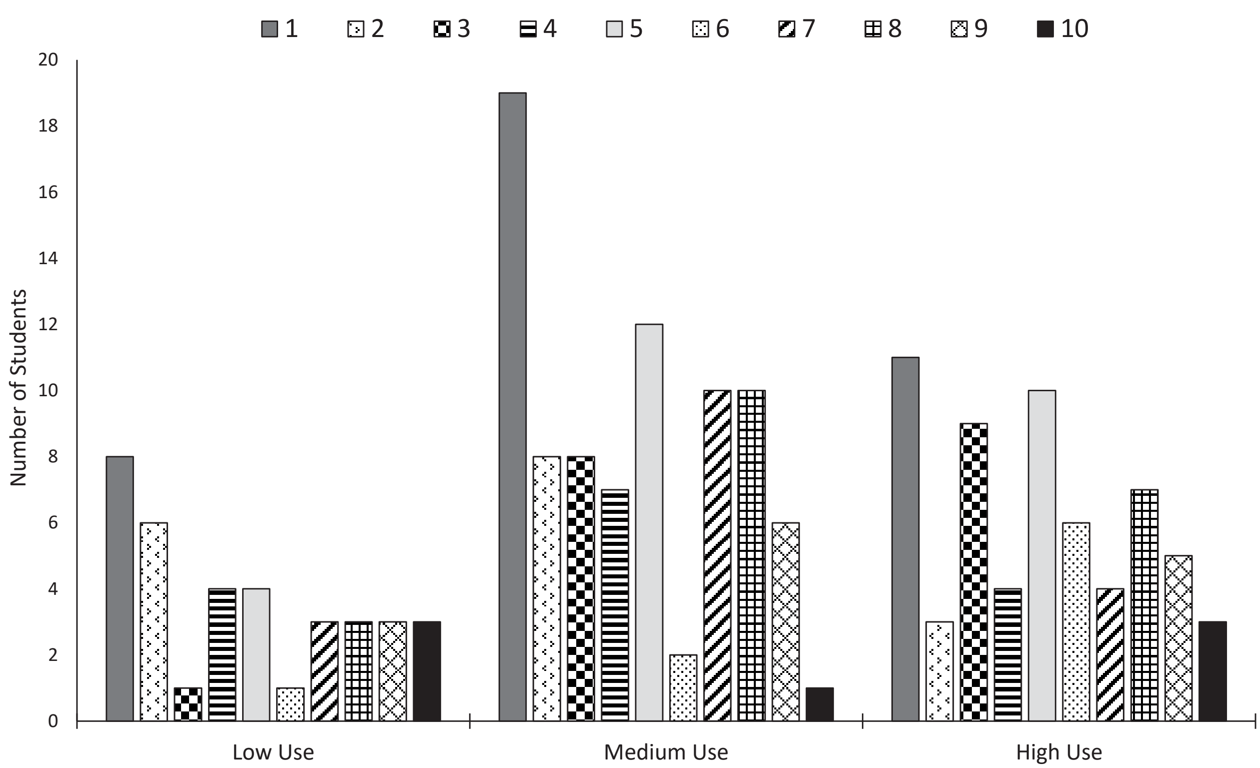

Figure 2. Human Anatomy and Physiology II student ratings of how easy it was to take pictures with their smartphones through the microscope lens with the microscope adapter with 1 meaning it was very hard to take pictures and 10 meaning it was very easy to take pictures.

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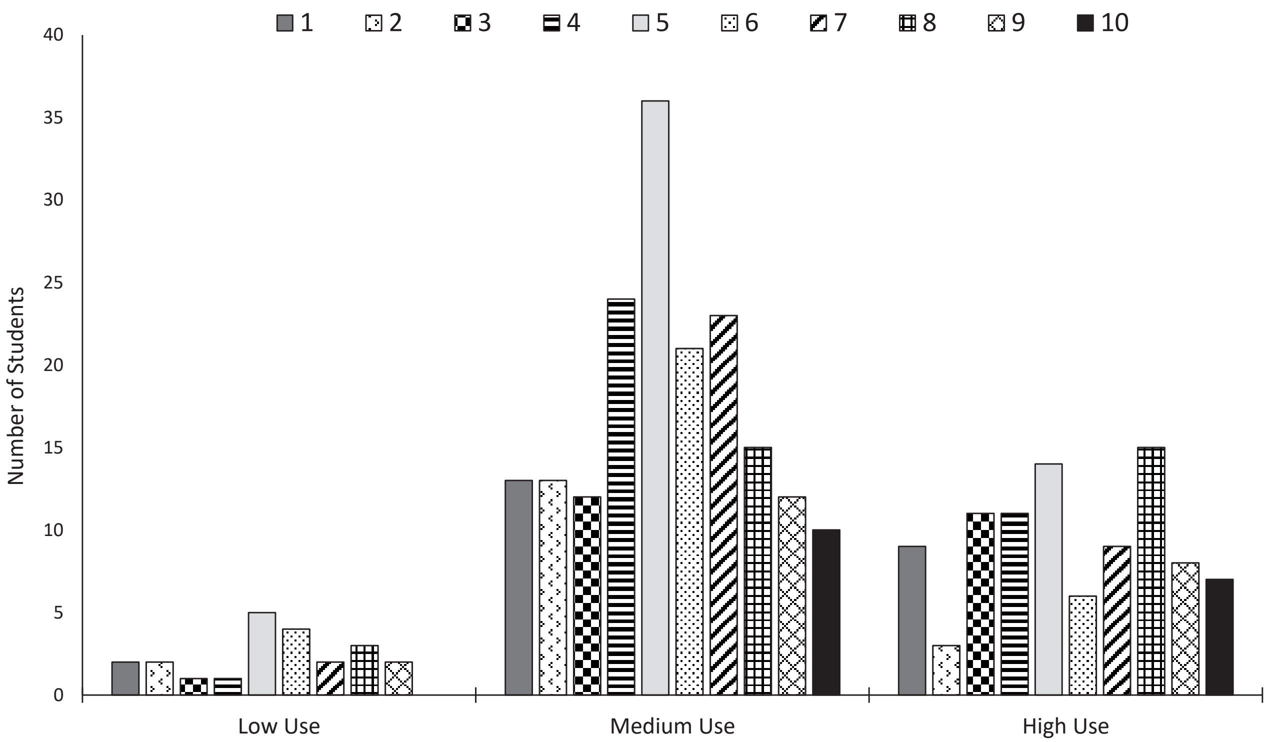

Figure 3. Human Anatomy and Physiology II student ratings of how easy it was to take pictures with their smartphones through the microscope lens with the microscope adapter with 1 meaning it was very hard to take pictures and 10 meaning it was very easy to take pictures.

Table 1. Student responses to Likert-style statements on the second survey (SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree; df = 4). *This question was only asked of Human A&P II students.

Statement	Course	Group	SA	A	N	D	SD	X^2	p-value
It was easy to identify specimens under the microscope with the use of my smartphone and the microscope adapter.	Human A&P II	Low Use	4	13	14	5	4	12.75	p<0.05
		Medium Use	6	28	21	15	6	24.13	p<0.001
		High Use	11	27	14	12	5	19.04	p<0.001
	Human A&P I	Low Use	2	8	5	5	2	5.727	p=0.220
		Medium Use	18	75	46	31	9	75.39	p<0.001
		High Use	19	39	22	12	3	37.58	p<0.001
It was easy to take pictures through the microscope lens with my smartphone and the microscope adapter.	Human A&P II	Low Use	6	7	10	8	5	2.056	p=0.726
		Medium Use	6	25	18	19	8	76	p<0.01
		High Use	13	16	19	14	7	5.710	p=0.222
	Human A&P I	Low Use	2	7	5	4	4	3.00	p=0.558
		Medium Use	22	67	38	43	6	59.85	p<0.001
		High Use	16	38	16	19	6	28.84	p<0.001
I found that even though my fellow classmates and I might be looking at the same microscope slide, we were able to take some different pictures of the same specimen.	Human A&P II	Low Use	4	11	16	3	2	20.39	p<0.001
		Medium Use	1	34	26	12	3	54.66	p<0.001
		High Use	4	26	24	13	2	35.42	p<0.001
	Human A&P I	Low Use	3	8	6	4	1	6.636	p=0.156
		Medium Use	17	86	51	25	0	125.8	p<0.001
		High Use	16	43	32	4	0	70.53	p<0.001
I believe that using my smartphone along with a microscope adapter to take higher quality pictures of histology slides on a microscope made it easier to study specimens under the microscope for the lab practicals.*	Human A&P II	Low Use	5	10	15	4	2	15.39	p<0.01
		Medium Use	6	20	28	13	8	21.87	p<0.001
		High Use	12	14	21	17	4	11.85	p<0.05

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Survey #1 Data
Students in Anatomy and Physiology II (spring 2016) had previously taken Anatomy and Physiology I where microscope adapters and smartphones were not available. Most (58%) of these students agreed with statements saying it was difficult to identify and study specimens under the microscope ($X^2 = 132.6$, df = 4, p<0.001) during the lab practicals in *Anatomy and Physiology* I ($X^2 = 125$, df = 4, p<0.001). Students in Anatomy and Physiology I (Fall 2016) were either new to the course or re-taking Anatomy and Physiology I from a previous year where microscope adapters and smartphones were not used in the laboratory. The Anatomy and Physiology I students were asked, "Have you ever used a microscope before," and most (97.2%) said yes ($X^2 = 310.6$, df = 1, p<0.001). To gauge how much experience they had with using microscopes, they were asked to rate their experience with microscopes on a scale of 1 (low) - 10 (high); the most common rating was a 5 ($X^2 = 117.5$, df = 9, p<0.001).

Students in *Anatomy and Physiology* II overwhelmingly responded "yes" to the question "Have you ever tried to use your smartphone to take a picture through a microscope lens without a microscope adapter" ($X^2 = 92.5$, df = 1, p<0.001), while Anatomy and Physiology I students responded "no" to this question ($X^2 = 72.6$, df = 1, p<0.001). Those who responded "yes" to this question were asked to rate the quality of the pictures that were taken by their smartphones through a microscope lens without a microscope adapter, with 1 being very low quality and 10 being very high quality. For those in Anatomy and Physiology II, the most common rating was a 4 ($X^2 = 69.2$, df = 9, p<0.001). For students in Anatomy and Physiology I, the most common rating was a 5 ($X^2 = 636.5$, df = 9, p<0.001). For this question, responses of students in Anatomy and Physiology II did not significantly differ from responses of students in Anatomy and Physiology I [$t_{(205)} = 0.617$, p = 0.528].

When responding to statements concerning student willingness to learn how to use something new to help them study tissues (e.g. using a microscope adapter with their smartphones to take pictures through a microscope), most students in both Anatomy and Physiology II (90.4%; ($X^2 = 213.5$, df = 4, p<0.001) and Anatomy and Physiology I (88.2%; ($X^2 = 432.2$, df = 4, p<0.001) either agreed or strongly agreed with these statements. In addition, most students in Anatomy and Physiology II (90.9%; ($X^2 = 214.3$, df = 4, p<0.001) and Anatomy and Physiology I (89.6%; ($X^2 = 487$, df = 4, p<0.001) agreed or strongly agreed with statements stating that they believe that using their smartphone as a learning tool in the laboratory will help improve their engagement in the laboratory and that using their smartphones along with a microscope adapter will make it easier to study specimens for the lab practicals.

Survey #2 Data
Students were asked how they used the adapters within their lab group. In Anatomy and Physiology II, most students claimed that they either took photos during every lab and shared them with their classmates, or they took only a few photos and contributed to sharing them with their classmates ($X^2 = 180.6$, df = 5, p<0.001; Figure 1). In Anatomy and Physiology I, most students claimed they took a few photographs and contributed to sharing them with their lab mates ($X^2 = 477.2$, df = 5, p<0.001; Figure 1). Students were classified and put into groups (low use=no photographs taken, medium use="a few" photographs taken, and high use=photographs taken during every lab) based on their responses to this question for further data analysis.

Students were also asked to rate from 1-10 the quality of pictures that were taken by their smartphones through the microscope lens with the use of the microscope adapter. Ratings were most common in the upper half of the scale for both Anatomy and Physiology II and Anatomy and Physiology I with 8 being one of the most common responses. Ratings within the low, medium, and high use groups were not significantly different in Anatomy and Physiology II ($F_{(2,176)} = 0.367$, p = 0.691) or Anatomy and Physiology I ($F_{(2,291)} = 0.883$, p = 0.415). For the ranked rating of the ease of taking pictures with their smartphone with the microscope adapter, student responses within the low use, medium use, and high use groups were analyzed with a one-way ANOVA. Responses were dispersed across the entire scale for all groups in both Anatomy and Physiology II ($F_{(2,178)} = 0.389$, p = 0.678; Figure 2) and Anatomy and Physiology I ($F_{(2,291)} = 0.267$, p = 0.766; Figure 3).

Most students in Anatomy and Physiology II and Anatomy and Physiology I significantly agreed that it was easy to identify specimens under the microscope using their smartphones and a microscope adapter for all groups except for the low use group in Anatomy and Physiology I (Table 1). More students in the medium use (Anatomy and Physiology II, Anatomy and Physiology I) and high use (Anatomy and Physiology I) groups agreed that it was easy to take pictures using their smartphone and the microscope adapter (Table 1). In response to the ease of taking different pictures of the same specimen, only the majority of medium and high users in Anatomy and Physiology II and Anatomy and Physiology I agreed with the statement (Table 1).

For students in Anatomy and Physiology II and Anatomy and Physiology I, significantly more students in the medium use and high use groups agreed with statements saying they believed using their smartphone as a learning tool helped improve their performance and engagement in the laboratory (Table 1). Significantly more students in the low use group were neutral towards the statement that said they believed using their smartphone helped improve their engagement (Anatomy and Physiology I and Anatomy and Physiology II) and performance (Anatomy and Physiology I) in the laboratory (Table 1). Within all usage groups, more students in Anatomy and Physiology II were neutral to the statement

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saying they believe using their smartphone with the adapter to take pictures made it easier to study specimens for the lab practicals (Table 1). Lastly, significantly more students in the low and medium use groups (Anatomy and Physiology II) and medium and high use groups (Anatomy and Physiology I) were neutral towards the statement that they like laboratory exercises that involve microscopes more because of the use of smartphones as a learning tool (Table 1). Significantly more students in the high use group (Anatomy and Physiology II) agreed with this statement (while significantly more students in the low use group (Anatomy and Physiology I) disagreed with it (Table 1).

Lab Practical Data

In Anatomy and Physiology II, average percent correct on histology-based questions from the first lab practical increased from 41.1% in Spring 2015 to 58.63% in Spring 2016, but this increase was not significant ($t_{(7)} = 2.17$, $p = 0.067$). For the second lab practical, scores decreased, 41.94% in spring 2015 to 35.98% in Spring 2016, but not significantly ($t_{(14)} = .0768$, $p = 0.455$). When both lab practicals were combined, there was a slight, but not significant, increase for the Spring 2016 semester with the average percent correct on lab practical questions being 45.42% compared to 41.66% in Spring 2015 ($t_{(22)} = 0.587$; $p = 0.563$).

In Anatomy and Physiology I, there was a slight, but not significant, increase in scores on the first lab practical during the Fall 2016 semester with an average percent correct of 42.29% on histological questions on the lab practical compared to the Fall 2015 semester whose average percent correct was 33.71% ($t_{(10)} =1.52$, $p = 0.159$). When both lab practicals were combined, there was a significant increase in lab practical scores with the average percent correct on lab practical questions rising from 31.85% (fall 2015) to 42.06% (fall 2016) ($t_{(13)} = 2.32$, $p = 0.038$). Lastly, there was no significant difference ($t_{(39)} = 1.34$; $p = 0.190$) in performance on histology-based questions between 2016 students (44.07% correct, adapters used) and 2015 students (38.25% correct, adapters were not used).

Discussion

Student Profiles and Engagement

Device equity was not a concern for the incorporation of smartphones in the laboratory in this study because almost all students owned some type of smartphone that allowed them to take pictures. Furthermore, it ensures that the prevalence of student mobile devices and technology offers an opportunity for schools and educators to use these devices for instructional purposes (Kiger and Herro 2015). Additionally most students have had some experience with microscopes prior to using the microscope adapters along with their smartphones. Familiarity and experience with using microscopes may have helped students to set up the microscope adapters onto the microscope.

Regarding their previous experiences, most Anatomy and Physiology II students significantly agreed that it was difficult to identify and study specimens under the microscope and responded that they tried to use their smartphones to take pictures of microscopic specimens without an adapter. These efforts led to pictures that were about average in terms of quality and students still admitted to having difficulty identifying specimens and studying for lab practicals. Most students in Anatomy and Physiology I, unlike those in Anatomy and Physiology II, had never tried to use their smartphone to take pictures of specimens through a microscope. For the few who had, the quality of pictures taken by their smartphones without a microscope adapter was average.

Similar to our results that showed that most students were willing to use something new in the laboratory to help them learn tissues, students in the Kafyulilo (2012) study felt comfortable learning with a mobile phone and thought that their use in the classroom could simplify learning and save time. Our students were optimistic about, and in favor of, the use of their smartphones with a microscope adapter as a tool to help them learn tissues and study for lab practicals. Students in the Brown *et al.* (2014) study similarly responded that they were willing to use response and engagement technology such as smartphones in the classroom to increase student engagement and that they desired to use technology in the classroom.

We *a priori* assumed that students would have varying levels of use with microscope adaptors. Our results show that not every student used the adapters to take photographs with their smartphone and not every student used the adapter during every lab. T he effects on student performance and engagement may differ among students who responded differently to this question because students who never used the microscope adapters will have a different experience and responses than those who used their smartphones to take pictures with the microscope adapter for every laboratory exercise.

Usage patterns, however, were not consistent across Anatomy and Physiology II and Anatomy and Physiology I students. Ratings within each usage group were expected to be low for the low use group, medium for the medium use group, and high for the high use group. These expected patterns were not apparent for students in Anatomy and Physiology II. For Anatomy and Physiology I, however, students in the low use group did have low ratings, while students in the medium use group had middle ratings, and students in the high use group had high ratings. The differences within these groups were significant.

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The quality of the pictures taken with smartphones and microscope adapters were overall rated as above average, but this was not significant for students in Anatomy and Physiology II or Anatomy and Physiology I. It was expected that the rankings of the quality of pictures taken with a microscope adapter would be higher than those of the quality of pictures taken without a microscope adapter. When the students were asked to give their ratings of the picture quality, there was no reference for them to compare the quality to.

Since the microscope adapters are compatible with multiple types of smartphones and provide an alignment of the camera lens with the microscope lens for high quality pictures, we expected that most students would agree that it was easy to take pictures and identify microscopic specimens with the use of the adapter. However, the ranked ease of taking pictures was dispersed across the scale for all usage groups, and these results were not significant for both Anatomy and Physiology II and Anatomy and Physiology I. These results could be due to individual differences in microscope and microscope adapter experience. For example, those in the high use group who used the adapters during every lab may have gained skill with using them through practice and experience. Those in the low use group, however, may not have had enough experience working with the adapters to gain the practice needed to easily attach their smartphones. Most groups in Anatomy and Physiology II and Anatomy and Physiology I significantly agreed that it was easier to identify specimens with use of the microscope adapter indicating that smartphones have the potential to be beneficial learning tools.

A study done in Tanzania found that pre-service teachers, students, and college instructors were in favor of the use of mobile phones as a teaching and learning tool in the classroom (Kafyulilo 2012). In our study most students in the high use group for Anatomy and Physiology II significantly agreed that they liked laboratory exercises that involve microscopes more because of the use of smartphones as a learning tool. Students in the other groups for Anatomy and Physiology II and Anatomy and Physiology I either disagreed or were neutral towards this statement, which was not expected. However, these students who claimed they rarely took photographs in the laboratory with the adapters and their smartphones did not have much experience with the adapters, which could account for their responses. From the student engagement results, we conclude that students perceived that the use of smartphones in the laboratory helped improve engagement and performance in the laboratory, and that the use of smartphones along with microscope adapter to take pictures of specimens may make it easier for students to study for histological questions on lab practicals.

Student Performance

Even though lab practical scores were shown to have been higher in most semesters where smartphones and microscope adapters were incorporated into the classroom, the increase in scores was not significant across all semesters. In addition, scores on the second practical in Anatomy and Physiology II were lower in Spring 2016 where the adapters and smartphones were used in the laboratory compared to Spring 2015 where adapters and smartphones were not used. Due to our IRB approval of comparing aggregate scores among students, we were not able to track individual scores or monitor student use of the adapters. With a higher level of IRB approval, however, we hypothesize that those who use the adapters during every laboratory will perform better on the laboratory practicals than those who rarely use the microscope adapter. Even though students shared pictures among their lab mates, the act of finding and photographing the pictures may be the formative learning tool. In addition, students who did not engage in the laboratory exercises by taking the photos directly with their phones may not have received all necessary pictures taken during each laboratory. It must be noted that the lab practical questions between semesters differ in both their content and precise placement, which could have affected the results.

Overall BYOD Effects

Our results are in agreement with other studies that have shown that the use of mobile phones and smartphones in science laboratories increases student engagement. The Ostrin and Dushenkov (2016) study found that the introduction of mobile phones into the Anatomy and Physiology laboratory along with content-specific application software resulted in an increase in student engagement and enthusiasm in the material. Their students perceived that using mobile devices in the Anatomy and Physiology laboratory was enjoyable, was effective in motivating them to learn the material, and resulted in a positive learning experience overall.

In addition, Harper *et al.* (2015) found that the use of student smartphones to take pictures of microscope specimens in an undergraduate botany class enhanced student engagement, and students reported that taking their own images helped them make better connections with what they were learning. Benham *et al.* (2014) found that students who perceived more benefits from the use of mobile devices in the classroom and who had a desire to use them reported greater engagement in the classroom. Similarly, our results on student performance are in agreement with those of Ostrin and Dushenkov (2016) who were also unable to confirm that introducing mobile phones and digital technology into the classroom increased student learning and understanding of the material and Sung *et al.* (2015) who found that mobile devices can improve educational effects, but concluded that the actual impact of mobile learning needs to be further assessed.

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In conclusion, the role that microscope adapters play in student performance is unclear. BYOD can be an effective way of engaging students and incorporating smartphones into the classroom interaction (Imazeki 2014). However, continuous research is needed to determine if smartphones and mobile learning have a true impact on student's learning (Gikas and Grant 2013).

Modifications and Future Considerations for Laboratory Education

We feel that static imagery of microscopic specimens does not take full use of the smartphone's capabilities. Rather than just capturing an image of a specimen under the microscope, a student could take a short video of the specimen on their phone. They could move the stage of the microscope around while the phone stays attached to the microscope so that the entire specimen can be viewed throughout the video. Taking a video would also allow the student to narrate facts about the specimen or tissue.

In addition, students can use different forms of social media such as the "GroupMe" application to share pictures taken with their lab group. Phone applications like "Snapchat" can allow the student to not only take a picture or video of the specimen, but also to write a caption, draw an arrow to a certain part of the specimen, and send the picture or video immediately to their lab group members. In addition, different types and brands of microscope adapters could be examined in future studies. Since most students had iPhones as their type of smartphone, it might have helped to have a digiscoping microscope adapter built specifically for iPhones.

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