BRING YOUR OWN DEVICE INITIATIVE TO IMPROVE ENGAGEMENT AND PERFORMANCE IN HUMAN ANATOMY AND PHYSIOLOGY I AND II LABORATORIES

by
Kelsey C. Hillhouse

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Approved by:

Advisor: Dr. Carol A. Britson

Reader: Dr. Sarah J. Liljegren

Reader: Dr. Colin R. Jackson

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ABSTRACT

KELSEY C. HILLHOUSE: Bring Your Own Device Initiative to Improve Engagement and Performance in Human Anatomy and Physiology I and II Laboratories
(Under the direction of Carol A. Britson)

At the University of Mississippi, just 4.93% (2014) and 6% (2015) of Human Anatomy and Physiology students responding to an informal, opinion survey stated that their favorite lab activity was using microscopes. In addition, performance on lab practical questions involving the identification of specimens under a microscope is low with the average percent correct being as low as 31.85% and no higher than 41.94%. These numbers are troubling in that Human Anatomy and Physiology I and II are required courses for students desiring entry into many allied health professions where knowledge of tissues, obtaining samples for biopsy, and interpreting microscopic specimens are critical to their job performance.

To increase students' interest and engagement with microscopy and tissue examination and performance on laboratory practicals, we purchased microscope adapters that simultaneously connect students' smartphones to the ocular lens of a microscope. These adapters allow students to take high quality pictures through the microscope with their mobile devices by aligning the focal points of the smartphone's camera lens with the microscope's ocular lens. These pictures could then be used by the student as a resource to study for the histological questions on the lab practical. To assess effectiveness of the adapters used with students' smartphones, aggregate scores (i.e., percent correct) for tissue questions on lab practicals were compared between semesters where adapters and smartphones were used and semesters where they were not used. Two surveys with Likert-style questions were used to assess student's levels of engagement in each semester.

Results from survey responses shows that the use of microscope adapters in the laboratory along with students' smartphones to take pictures of specimens through a microscope has the potential to improve student engagement in the laboratory. Results show that lab practical scores were higher in semesters where microscope adapters and smartphones were used compared to semesters where they were not used, but the increase in scores was not significant. The use of students' smartphones along with microscope adapters in the laboratory has the potential to improve student engagement, but the role that it plays in student performance is still unclear.

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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 has occurred at an increasing rate over the past years (Falaki et al., 2010; Soikkeli et al., 2013). From 2011 to 2015, the ownership of smartphones among adults has risen from 35% to 68% (Anderson, 2015). Due to increasing affordability and more advanced applications, smartphones have become integrated into users' everyday lives (Soikkeli et al., 2013; Chan et al., 2014). They 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). However, it is still not supported by some instructors.

This may be because they don’t know how to use the technology appropriately themselves (Gikas and Grant, 2013). 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 less than 32 (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.

Use of microscopes in the study of biological tissues (i.e., histology) is a particularly challenging area of study for students in Human Anatomy and Physiology at the University of Mississippi. In the fall of 2014, 59.18% of students who responded 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 responding students who stated that their favorite lab activity was using the microscopes was only 4.93% in 2014 and 6% in 2015. In addition, performance on lab practical questions involving the identification of specimens under a microscope is low with the average percent correct being as low as 31.85% and no higher than 41.94%. These numbers are troubling in that 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 their job performance. For example, it has been found that students’ prior histological knowledge is a predictor of medical students' performance in diagnostic pathology, confirming the value of students having a strong background in the basic medical sciences (Nivala et al., 2013).

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 to try to take pictures of the microscope slides by holding their phone's camera lens over the ocular lens of the microscope and trying to capture a clear picture. 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." Therefore, this process is time consuming and the pictures taken are of low quality. It wasn't until 2012 that companies started manufacturing accessories such as microscope adapters which help smartphones attach to a microscope (Morrison and Gardner, 2015). These microscope adapters allow the students to take high quality pictures through the microscope with their mobile devices in the laboratory by aligning the focal points of the lenses. It is anticipated that traditional digital microscope cameras will be replaced with smartphone cameras as smartphone camera technology advances because of smartphone camera technology advances along with their "low cost, widespread availability, and ease of use" (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). This has led to the adoption of pedagogies which emphasize student engagement (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 these undergraduate life science courses. High structure course methods involving active learning have been shown to increase student engagement and performance (Shaffer, 2016). Use of smartphones in the laboratory along with a microscope adapter as an active learning method may allow for the same effects. Student engagement and performance is affected by other aspects as well. Sturges et al. (2016) have shown that there is a significant relationship between students' GPA, how many hours of studying students reported, overall self-reported motivation, and academic performance in undergraduate Human Anatomy and Physiology courses. They have also shown that student's autonomous motivation is associated with student interest, creativity, effort, persistence, and performance (Sturges et al., 2016). In addition, student engagement in classrooms is related to the students' perceived benefits of the mobile technology as well as the students' desire to use the mobile technology (Benham et al., 2014).

There are many potential benefits for educators and students when it comes to the incorporation and use of smartphones in the laboratory. Allowing students to take pictures of the microscope slides on their phones may make the student's feel a confidence that they have the information they need to study for the histology questions and, therefore, increase the amount of self-efficacy they have when it comes to answering those questions. This increase in self-efficacy could translate into improved performance and learning outcomes because of higher confidence levels (Solberg, 2012). Also, use of smartphones in the classroom as well as the convenience of having the microscope slide pictures on the student's mobile devices may motivate students and encourage them to spend more time studying the material that will be on the practicals. Mobile devices such as smartphones are convenient and flexible learning tools in that they 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 practical do better on the practicals (Cogdell et al., 2012). Lab practical questions in anatomy courses often take the format of a "steeplechase" method which involves student identification of anatomical structures on items such as plastic models, cadavers, and radiological or histological images (Inuwa et al., 2011). Questions are often of the free response format where the student writes the answer down on their answer sheet using their own words rather than selecting the answer from a list of multiple choice items, and the students' responses are graded manually by academic staff which may include the teaching assistants of the laboratory (Shaibah and Vleuten, 2013).

More efficient laboratory activities can increase student performance because the student is more able to focus on tasks at hand and obtain information rather than rushing to complete the laboratory exercise. The fact that most students (because of their age) are familiar with mobile devices can increase efficiency which is beneficial in short lessons (Hartnell-Young et al., 2008). In addition, there are many utilities built into smartphones that increase the learning opportunities for students such as allowing students to time experiments with a stopwatch, photograph white boards or models for future review, and to create short narrative movies, etc. (Hartnell-Young et al., 2008). More specifically, camera features of smartphones allow for scientific visualization and are capable of recording audio and video which supports “differentiation of instruction by appealing to audio or visual learners” (Thomas et al., 2014). Use of mobile devices in the laboratory could also improve student engagement within the laboratory, expand the learning environment, and promote the productiveness of faculty and students (Dahlstrom, 2013).

There are potential drawbacks associated with allowing students to use their mobile phones in a laboratory. Some concerns include device theft, security, equity, distractions in the classroom, and inappropriate use (Thomas et al., 2014; Kiger and Herro, 2015). In the United Kingdom, smartphones have been disruptive in school education, rather than useful (Hartnell-Young et al., 2008). In Kafyulilo (2012), in-service teachers were against the use of mobile phones being used in a classroom because their students use smartphones in the classroom to engage in activities such as flirting or texting rather than for educational purposes and because smartphones contribute to plagiarism which inhibits the student’s “capability for self learning.” These concerns, however, do not pertain to college students that are the focus of this study. According to Kafyulilo (2012), 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, there are also issues surrounding pedagogy, referring to the method and practice of teaching children (Kiger and Herro, 2015). The use of smartphones for teaching purposes in the laboratory does not necessarily make them appropriate, pedagogically or andragogically (referring to the method and practice of teaching adult learners), so there is a need to investigate their pedagogical and andragogical efficacy. The purpose of my study is to provide an evidence-based resource for educators considering implementing the use of students' smartphones and mobile devices in the laboratory. My hypothesis is that use of microscope adapters with the students' smartphones will improve student engagement in the laboratory and performance on histology-based questions on lab practicals. This study will serve as an invaluable resource in the debate of curricular incorporation of smartphones and will help inform educators, schools, and universities about the effects of incorporating students' smartphones into the laboratory for learning purposes.

MATERIALS AND METHODS

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. BISC 206 and BISC 207 represent a two-semester course sequence in which students must successfully complete BISC 206 (with a C or better) before taking BISC 207. In a traditional academic year, BISC 206 is only offered in the fall semesters (approximately 390 students enrolled in one lecture section and 13 lab sections) and BISC 207 is only offered in the spring semesters (approximately 250 students enrolled in one lecture section and 9-10 lab sections). Five hundred and fifty-six students participated in this study, and it highly unlikely any of these students were repeats since students in BISC 207 of spring 2016 had already passed BISC 206 and would, therefore, not enroll in BISC 206 during fall 2016. 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. My protocol was approved as Exempt under 45 CFR 46.101(b)(#1 & 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.

Sixteen universal digiscoping adapters [Carson Hookupz™ (IS-100) Universal Smartphone Optics Adapter from Carson Optics] were purchased for this experiment with a 2015 Technology Integration Grant from the University of Mississippi. These adapters attach simultaneously to students' smartphones and the ocular lens of a microscope. They 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. Since the adapters are self-centering, only one initial phone alignment is needed to set up the phone and microscope with the adapter. 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. It is compatible with most microscopes, including slit lamp microscopes, binoculars, monoculars, endoscopes, etc. (Carson Optics, 2016). Other adapters were available at the time I purchased these adapters, 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). In addition, there are adapters available now that were not available at the time of purchase of our adapters. For example, the HookUpz™ 2.0 Universal smart phone optical adapter (IS-200) from Carson Optical is a newer version of the adapter we purchased (Carson Optics, 2017a). Also, there are other Carson HookUpz™ adapters made to fit specific iPhone models (Carson Optics, 2017b).

The microscope adapters were used in the laboratory during the spring 2016 (BISC 207 students) and fall 2016 semesters (BISC 206 students). These BISC 207 students had previously taken BISC 206 where they did not use their smartphones along with microscope adapters. These microscope adapters allowed the students to digitally capture any microscopic images they might need to know and identify on the lab practical. These pictures could then be used by the student as a resource to study for the histological questions on the lab practical. They also could share captured microscopy with each other via text message, social media, or email.

Two surveys were given to participants over the course of the semester to students in BISC 207 (spring 2016) and BISC 206 (fall 2016). These survey instruments were used to assess 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. The survey questions were predominantly Likert-style and asked participants to give a rating from strongly agree to strongly disagree in response to each statement.

At the beginning of the semester and after being given a verbal description of this study, the first survey was administered to the students in the laboratory. The 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 (Appendix A). 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 in the laboratory 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 were given in both fall 2015 and fall 2016 for BISC 206 and both spring 2015 and spring 2016 for BISC 207. These lab practicals contained 1-10 histology based questions on each lab practical. Questions involved identifying anatomical structures through a microscope and required students to write their answers down on a blank answer sheet in a free response format. These questions were then graded manually by the teaching assistants of each laboratory.

Analytical Methods

Descriptive statistics (e.g., mean and standard deviation) were calculated for all survey data and quantitative lab practical performance data. The level of significance was set at $\alpha = 0.05$ for all analyses. Statistical tests were performed using Microsoft Excel and StatPlus.

Aggregate performance (i.e., percent correct) on each lab practical histology question was measured by dividing the number of correct responses for each histological lab practical question by the total number of student responses per question. For BISC 206, performance on the histology-based questions from each of the two lab practicals were compared between the fall 2015 semester (microscope adapters were not used) and the fall 2016 semester (microscope adapters were used). For BISC 207, performance on the histology-based questions from each of the two lab practicals were compared between the spring 2015 semester (microscope adapters were not used) and the spring 2016 semester (microscope adapters were used). Percent correct data were analyzed using two-tailed t-tests assuming unequal variances.

On the first survey, Likert-style questions asking students to respond to statements with a rating of strongly agree, agree, neutral, disagree, or strongly disagree were analyzed with Chi-square analyses. In addition, one question concerning the students' ratings from 1-10 of the quality of the pictures that were taken by their smartphones through a microscope lens without the use of a microscope adapter was analyzed using a two-tailed, t-test assuming unequal variances.

On the second survey, students were categorized into groups based off their responses to the question asking how the microscope adapters were used in their lab groups. Students that chose an option stating they did not take any photographs were categorized into the low use group. Students that chose an option stating they took a few photographs were categorized into the medium use group. Lastly, students that chose an option stating they took photographs during every lab were categorized into the high use group. Within these groups, Chi-square analyses were performed for Likert-style questions. In addition, one-way ANOVAs were performed within these groups for questions asking the students to respond with a rating from 1-10.

RESULTS

Student Profiles

Enrollment data shows that most of the students enrolled in Human Anatomy and Physiology I and II are pursuing some career in an allied health profession, 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 (Figure 1). Since their majors do not automatically translate into their chosen profession, students in BISC 206 were asked “What profession are you planning on going into?” on the second survey. 105 students stated nurse, 56 students stated physical therapist, 20 students stated occupational therapist, 18 students stated dietician, and 17 students stated physician assistant (Figure 2). All but two students who took BISC 206 or BISC 207 owned some type of smartphone that allowed them to take pictures. The majority of students, specifically 441, who took BISC 206 or BISC 207 had an iPhone with only 32 students owning a different type of smartphone such as an Android (Table 1). In addition, most students, specifically 257, reported having 16 gigabytes (GB) of memory available on their smartphone (Table 2).

Survey #1 Data

Students in BISC 207 (spring 2016) had previously taken BISC 206 in a semester where microscope adapters and smartphones were not used in the laboratory. Most of these students agreed with statements saying it was difficult to identify and study specimens under the microscope for the lab practicals during BISC 206 (Table 3). Students in BISC 206 (fall 2016) were either new students to the course or re-taking BISC 206 from a previous year where microscope adapters and smartphones were not used in the laboratory. These students were asked “Have you ever used a microscope before,” and most students, specifically 345, said yes while only 12 said no (X^2 = 310.6, d.f. = 1, p<0.001). To further gauge how much experience they have had with using microscopes, these students were asked to rate their experience with microscopes on a scale of 1-10, with 1 meaning very little experience and 10 meaning very much experience. The most common rating was a 5 (X^2 = 117.5, d.f. = 9, p<0.001; Figure 3).

Students in BISC 207 responded yes in response 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, d.f. = 1, p<0.001). Most students in BISC 206, however, responded no to this same question (X^2 = 72.6, d.f. = 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 BISC 207, the most common rating was a 4 (X^2 = 69.2, d.f. = 9, p<0.001; Figure 4). For students in BISC 206, the most common rating was a 5 (X^2 = 636.5, d.f. = 9, p<0.001; Figure 4). For this question, responses of students in BISC 207 did not significantly differ from responses of students in BISC 206 [$t_{(205)}$ = 0.617, p = 0.528].

When responding to statements concerning student’s willingness to learn how to use something new to help them learn tissues, the idea of using their smartphones in the laboratory, and the idea of using a microscope adapter with their smartphones to take pictures through a microscope, most students in both BISC 207 and BISC 206 either agreed or strongly agreed with these statements (Table 3). In addition, most students in either BISC 207 or BISC 206 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 (Table 3).

Survey #2 Data

Students were asked how they used the adapters within their lab group. In BISC 207, most students claimed 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, d.f. = 5, p<0.001; Figure 5). In BISC 206, most students claimed they took a few photographs and contributed to sharing them with their lab mates (X^2 = 477.2, d.f. = 5, p<0.001; Figure 5). Students were classified and put into groups (low use, medium use, and high use) based off their responses to this question for further data analysis.

A one-way ANOVA was performed within groups A, B, and C on students' ratings from 1-10 of how much they used the microscope adapter along with their smartphone in the laboratories that involved looking at specimens through the microscope. In BISC 207, the low use group tended to have low ratings, while the medium and high use groups tended to have ratings dispersed throughout the scale [Figure 6; $F_{(2,177)}$ = 1.61, p = 0.202]. In BISC 206, the low use group tended to have dispersed ratings throughout the scale, the medium use group tended to have ratings in the middle of the scale, and the high use group tended to have high ratings [Figure 6; $F_{(2,293)} = 3.45$, p = 0.033]. Students were also asked to rate from 1-10 of the quality of pictures that were taken by their smartphones through the microscope lens with the use of the microscope adapter. Ratings were most commonly in the upper half of the scale for both BISC 207 and BISC 206 with 8 being one of the most common responses within the groups. The responses within the low use, medium use, and high use groups (Figure 7) were not significant among responses of students in BISC 207 ($F_{(2,176)} = 0.367$, p = 0.691) or BISC 206 ($F_{(2,291)} = 0.883$, p = 0.415). A one-way ANOVA was also performed within these groups on students' ratings from 1-10 of the ease of use of the microscope adapter, and responses (Figure 8) for all groups were dispersed across the scale for both BISC 207 ($F_{(2,177)} = 0.200$, p = 0.819) and BISC 206 ($F_{(2,292)} = 1.77$, p = 0.173). For the rating from 1-10 of the ease of taking pictures with their smartphone through the microscope lens with the microscope adapter, student responses within the low use, medium use, and high use groups were analyzed with a one-way ANOVA. Responses (Figure 9) were dispersed across the entire scale for all groups in both BISC 207 ($F(2,178) = 0.389$, p = 0.678) and BISC 206 ($F(2,291) = 0.267$, p = 0.766).

Within the low use, medium use, and high use groups, most students in BISC 207 and BISC 206 agreed that it was easy to identify specimens under the microscope using their smartphones and a microscope adapter, and these results were significant for all groups except for the low use group in BISC 206 (Table 4). For students in BISC 207, most students in the low use and high use groups said they were neutral to the statement saying it was easy to take pictures using their smartphone and the microscope adapter, but these results were not significant (Table 4). Students in the medium use group, however, significantly agreed with this statement (Table 4). In BISC 206, most students in all groups agreed that it was easy to take pictures using their smartphone and the adapter, but the results were only significant for the medium use and high use groups (Table 4). Most students in the medium use and high use groups for both BISC 207 and BISC 206 significantly agree that they could take some different pictures of the same specimen on a single microscope slide (Table 4). In response to the same statement, students in the low use group for BISC 207 significantly responded that they were mostly neutral while results for the low use group of BISC 206 students were not significant (Table 4).

For students in BISC 207 and BISC 206, significantly more students in the medium use and high use groups either agreed or strongly agreed with statements saying they believed using their smartphone as a learning tool helped improve their performance and their engagement in the laboratory (Table 4). Significantly more students in the low use group for BISC 206 and BISC 207 were neutral towards the statement that said they believed using their smartphone helped improve their engagement in the laboratory (Table 4). Regarding whether they believed using their smartphone improved their performance in the laboratory, significantly more students in the low use group for BISC 206 responded as neutral (Table 4). However, low use group responses to this statement for student in BISC 207 were not significantly different (Table 4). Furthermore, significantly more students in BISC 207 responded that they were neutral to the statement saying they believe using their smartphone with the adapter to take pictures made it easier to study specimens for the lab practicals (Table 4).

Lastly, significantly more students in the low use and medium use groups for BISC 207 were neutral towards the statement that they like laboratory exercises that involve microscopes more because of the use of smartphones as a learning tool while significantly more students in the high use group for BISC 207 agreed with this statement (Table 4). In BISC 206, significantly more students in the medium use and high use groups were neutral towards this statement while significantly more students in the low use group disagreed with it (Table 4).

Lab Practical Data

In BISC 207, average percent correct on lab practical 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 in BISC 207, 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 in 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 BISC 206, 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 being 31.85% in fall 2015 and 42.06% in 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

Device equity was not a concern for the incorporation of smartphones in the laboratory in this study because most students (over 99%) owned some type of smartphone that allowed them to take pictures. Furthermore, it ensures that the prevalence of students' mobile devices and technology offers an opportunity for schools and educators to use these devices for instructional purposes (Kiger and Herro, 2015). Most of the students owned iPhones rather than some other type of brand of smartphone such as an Android or Windows Mobile so there was no issue seen with the microscope adapters in terms of adapter compatibility with the students' smartphones. In addition, most students reported having 16 gigabytes of memory on their phones so the amount of storage on their phones for pictures taken in the laboratory was not a concern for this study.

Student Engagement

All students in BISC 207 had previously taken BISC 206, and had, therefore, used a microscope before. Most students in BISC 206 responded on the first survey that they had used a microscope before as well. Most students using the microscope adapters along with their smartphones have had some experience with microscopes prior to using the microscope adapters along with their smartphones. Familiarity with and experience with using microscopes may have helped students to set up the microscope adapters onto the microscope.

Regarding their previous experiences in BISC 206, most of the students in BISC 207 significantly agreed that it was difficult to identify and study specimens under the microscope for the lab practicals. In addition, most responded that they tried to use their smartphones to take pictures of microscopic specimens without an adapter, and the most common rating of picture quality was a 4. These results show that using their smartphones to take pictures through a microscope without an adapter led to pictures that were about average in terms of quality, and these students still admitted to having difficulty identifying specimens and studying for the lab practicals. In addition, these results further promote the need of using a microscope adapter along with students' smartphones to take high quality pictures of specimens through a microscope lens as a new method to help improve student engagement and performance on the laboratory practicals.

Most students in BISC 206, unlike those in BISC 207, had not ever tried to use their smartphone to take pictures of specimens through a microscope without a microscope adapter before. For the few who had, the quality of pictures taken by their smartphones without a microscope adapter was of average quality. In addition, there was no significant difference between the ratings of the quality of pictures taken without the use of microscope adapters between students in BISC 207 and those in BISC 206. These results further confirm that the quality of pictures taken by smartphones through a microscope without the use of microscope adapters were about average.

Prior to using the adapters, most students in BISC 207 and BISC 206 agreed with statements concerning their willingness to use something new in the laboratory, such as a microscope adapter along with their smartphone, to help them learn tissues. Similarly, most of the students in the Kafyulilo (2012) study reported that they felt comfortable learning using a mobile phone and thought that their use in the classroom could simplify learning and save time. In addition, most students in this study agreed or strongly agreed with statements stating they believe using their smartphone as a learning tool would help improve their engagement in the laboratory and would make it easier to study for the lab practicals, and these responses were significant. These results show that most students were optimistic about and in favor of the use of their smartphones in the laboratory as a learning tool along with a microscope adapter to help them learn tissues and study for the lab practicals, and that most students thought it would also help improve their engagement in the laboratory exercises. Similarly, students in the Brown et al. (2014) study 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.

After using the microscope adapters, students were asked how they used the adapters within their lab group. Results to this question shows that not every student used the adapters to take photographs and not every student used the adapter during every lab. The 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.

Therefore, responses for the remaining data was analyzed within three groups based off responses to this question with the low use group made up of students who didn't take any photographs, the medium use group made up of students who took only a few photographs, and the high use group made up of students who took photographs for every laboratory.

Ratings within these groups of how much the students used the microscope adapter with their smartphone in the laboratories were expected to be low for the low use group, medium for the medium use group, and high for the high use group. However, they were not significantly different for students in BISC 207. For BISC 206, however, students in the low use group tended to have low ratings, students in the medium use group tended to have middle ratings, and students in the high use group tended to have high ratings for this question, and the difference within these groups was significant. These results show that the amount that students used the adapter and took pictures varied more within each group in BISC 206 than in BISC 207.

The quality of pictures taken with students' smartphones and the microscope adapters was most commonly rated an 8 on a scale from 1 to 10 meaning that the pictures were overall rated as above average quality, but this was not significant for students in BISC 207 and BISC 206. 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. Therefore, the responses are based on each students' own perceptions of picture quality.

Ratings of the ease of using the microscope adapters and the ease of taking pictures through a microscope with the use of a microscope adapter were expected to be high. However, these results were not significant for both BISC 207 and BISC 206. In addition, the ease of taking pictures through a microscope with a smartphone and a microscope adapter were also dispersed across the scale for all groups, and these results were not significant for both BISC 207 and BISC 206 as well. 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 at 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.

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, I expected that most students would agree that it was easy to identify and take pictures of microscopic specimens with the use of the microscope adapter. Most groups in BISC 207 and BISC 206 significantly agreed that it was easier to identify specimens with use of the microscope adapter. In response to whether the students thought it was easy to take pictures with the use of the microscope adapter, most groups in BISC 207 were neutral while most groups in BISC 206 agreed, but not significantly. These results show that the microscope adapters are effective in making it easier for students to identify specimens under a microscope, and that smartphones have the potential to be beneficial learning tools.

Since the microscope adapters attach to the ocular lens of the microscope, and, therefore, do not interfere with movement of the stage of the microscope, I expected that most students would agree they were able to take different pictures of the same specimen on a single microscope slide. As expected, most students in the medium use and high use groups for both BISC 207 and BISC 206 significantly agreed. However, responses of the low use group were either mostly neutral or not statistically significant. These results show that most students who had experience using the adapters and taking pictures with the adapters could take different pictures of the same specimen on a slide, and this was expected. The responses of students in the low use group could be due to those students admitting that they never took photos with the adapter. Therefore, they would not be able to respond to this statement correctly.

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). Based off these student perception results of Kafyulilo (2012), I expected most students to agree that using their smartphone as a learning tool helped improve both their performance and their engagement in the laboratory. As expected, most students in the medium use and high use groups for both BISC 207 and BISC 206 significantly agreed while most students in the low use group were neutral towards these statements. Furthermore, most students in BISC 207 were neutral to the statement saying they believe using their smartphones with the microscope adapter to take pictures made it easier to study specimens for the lab practicals. In addition, as expected, most students in the high use group for BISC 207 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 BISC 207 and BISC 206 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 do not have much experience with the adapters which could explain their responses. From the student engagement results, it can be concluded overall that students mostly 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 students' smartphones and the microscope adapters were incorporated into the classroom, this increase in scores was not significant across all semesters. In addition, it was shown that scores on the second practical in BISC 207 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 allowed to track individual scores or monitor students' use of the adapters. If we gained higher IRB approval, however, I would hypothesize that those who used the adapters during every laboratory performed better on the laboratory practicals than those who rarely used 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, it may be the case that the 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 also be noted that the lab practical questions between semesters could differ in both their content and placement in the test which could have affected the results.

Overall BYOD Effects

Results from survey responses gives evidence that the use of microscope adapters in the laboratory along with students' smartphones to take pictures of specimens through a microscope has the potential to improve student engagement in the laboratory. Other studies 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 & Physiology laboratory along with content-specific application software resulted in an increase in student engagement and enthusiasm in the material. These students perceived that using mobile devices in the Anatomy & Physiology laboratory was enjoyable, was effective in motivating them to learn the material, and resulted in a positive learning experience overall (Ostrin and Dushenkov, 2016). In addition, Harper et al. (2015) found that the use of students' 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.

Lab practical scores increased in semesters where microscope adapters and smartphones were used compared to semesters where they were not used, but the change in scores was not significant. Ostrin and Dushenkov (2016) were also not able to confirm that introducing mobile phones and digital technology into the classroom increased student learning and understanding of the material. According to Sung et al. (2015), mobile devices can improve educational effects, but the actual impact of mobile learning needs to be further assessed.

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

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 to also 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 used in further studies. Since most students had iPhones as their type of smartphone, it might would have helped to have a digiscoping microscope adapter built specifically for iPhones. Students may enjoy the laboratory exercises more if given microscope adapters that are easier to use or that are more compatible to their smartphone, and this could improve engagement in the laboratory as a result.

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Table 1. Types of smartphones owned by students in BISC 207 and BISC 206.

Course	Type of Smartphone					X^2	p-value
	iPhone	Android	Blackberry	Windows Mobile	Other		
BISC 207	174	8	0	1	0	646.0	$p<0.001$
BISC 206	267	15	0	0	1	980.5	$p<0.001$

Table 2. Amount of memory available on students' smartphones in BISC 207 and BISC 206.

Course	**Amount of Memory on Smartphone (GB)**					X^2	**p-value**
	8	**16**	**32**	**64**	**128**		
BISC 207	29	89	37	34	5	97.5	$p<0.001$
BISC 206	37	168	57	81	13	199.8	$p<0.001$

Table 3. Student responses to Likert-style statements on the first survey (SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree; df = 4).

Statement	Course	SA	A	N	D	SD	X^2	p-value
It was difficult to identify specimens under the microscope in BISC 206.	BISC 207	17	99	40	34	6	132.6	p<0.001
It was difficult to study specimens under the microscope for the lab practicals in BISC 206.	BISC 207	43	97	25	26	5	125.0	p<0.001
I am willing to learn how to use something new in order to help learn tissues and organs.	BISC 207	93	98	4	1	1	266.7	p<0.001
	BISC 206	263	75	6	0	2	735.4	p<0.001
The idea of using my smartphone as a learning tool in the laboratory is appealing to me.	BISC 207	81	88	23	3	2	179.8	p<0.001
	BISC 206	177	114	45	5	5	324.5	p<0.001
The idea of using my smartphone along with a microscope adapter to take high quality pictures of tissue slides on a microscope is appealing to me.	BISC 207	96	82	15	3	1	213.5	p<0.001
	BISC 206	201	112	30	1	2	432.2	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 will make it easier to study specimens under the microscope for the lab practicals.	BISC 207	88	91	13	3	2	214.3	p<0.001
	BISC 206	216	102	24	2	2	487.0	p<0.001
I believe that using my smartphone as a learning tool will help improve my engagement in the laboratory.	BISC 207	75	79	33	8	2	133.5	p<0.001
	BISC 206	170	112	53	9	2	294.7	p<0.001

Table 4. Student responses to Likert-style statements on the second survey (SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree; df = 4).

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.	BISC 207	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
	BISC 206	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.	BISC 207	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
	BISC 206	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.	BISC 207	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
	BISC 206	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.	BISC 207	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

Table 4 cont.

Statement	Course	Group	SA	A	N	D	SD	X^2	p-value
I believe that using my smartphone as a learning tool helped improve my performance in the laboratory.	BISC 207	Low Use	10	9	10	6	1	8.167	p=0.086
		Medium Use	14	30	18	12	2	27.16	p<0.001
		High Use	27	26	6	8	2	40.35	p<0.001
	BISC 206	Low Use	1	7	10	2	2	13.91	p<0.01
		Medium Use	37	78	43	17	4	89.35	p<0.001
		High Use	20	47	21	5	2	67.05	p<0.001
I believe that using my smartphone as a learning tool helped improve my engagement in the laboratory.	BISC 207	Low Use	9	7	13	6	1	10.67	p<0.05
		Medium Use	14	36	13	9	4	39.66	p<0.001
		High Use	25	24	13	5	2	32.38	p<0.001
	BISC 206	Low Use	0	10	12	0	0	33.45	p<0.001
		Medium Use	22	77	45	21	1	101.5	p<0.001
		High Use	34	44	21	7	1	60.43	p<0.001
I like laboratory exercises that involve microscopes more because of the use of smartphones as a learning tool.	BISC 207	Low Use	0	5	18	7	6	24.28	p<0.001
		Medium Use	9	16	25	20	6	15.97	p<0.01
		High Use	10	21	17	15	6	10.06	p<0.05
	BISC 206	Low Use	0	5	7	8	2	10.27	p<0.05
		Medium Use	14	38	67	47	14	57.06	p<0.001
		High Use	8	25	41	15	6	43.47	p<0.001

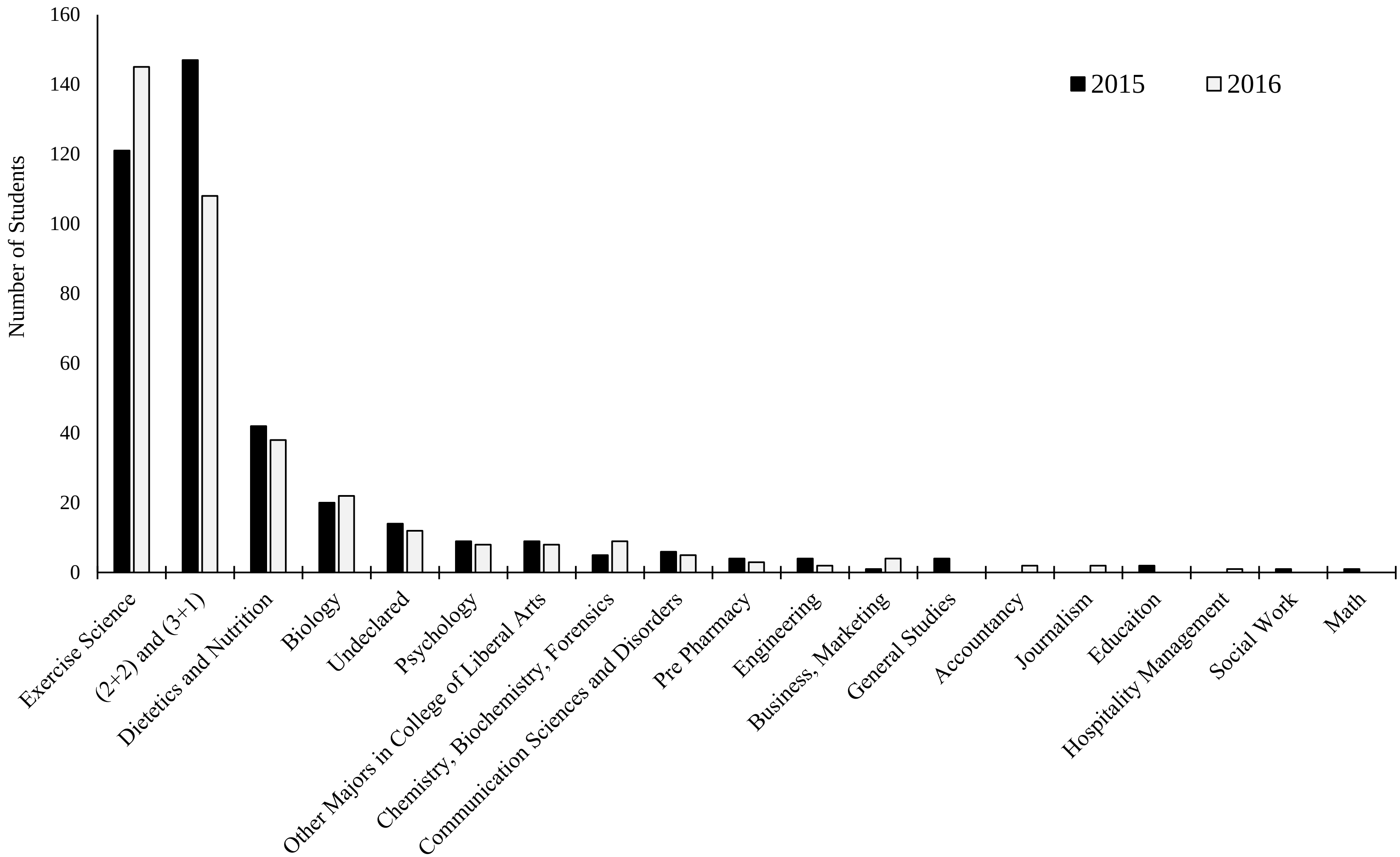

Figure 1. Majors of students enrolled in BISC 206 in fall 2015 and fall 2016.

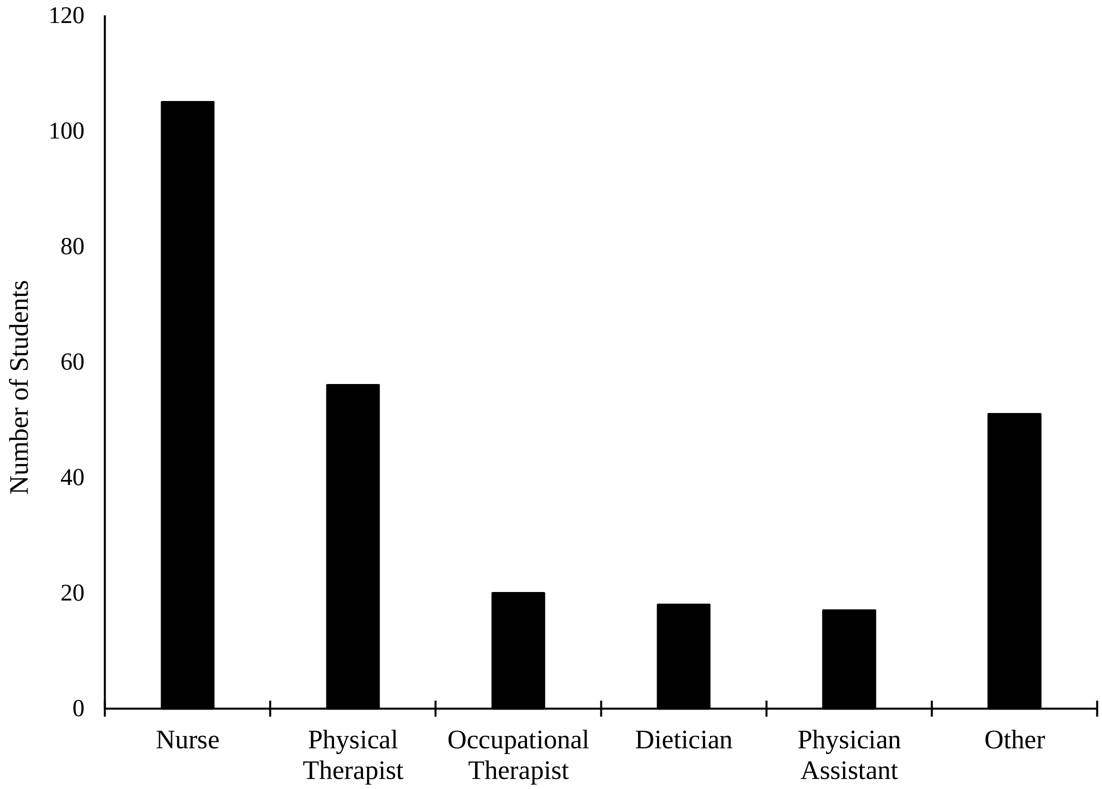

Figure 2. Common future professions of students in BISC 206 in fall 2016.

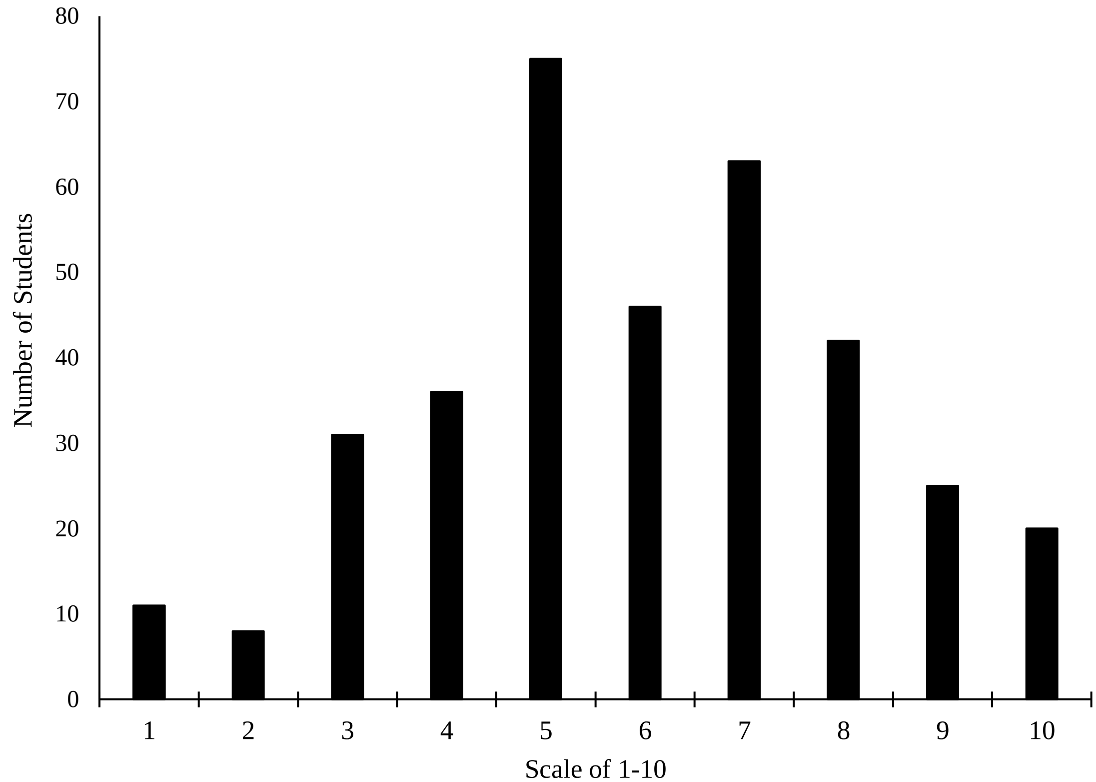

Figure 3. Student ratings of how much experience they have using microscopes prior to taking BISC 206 with 1 being very little experience and 10 being very much experience.

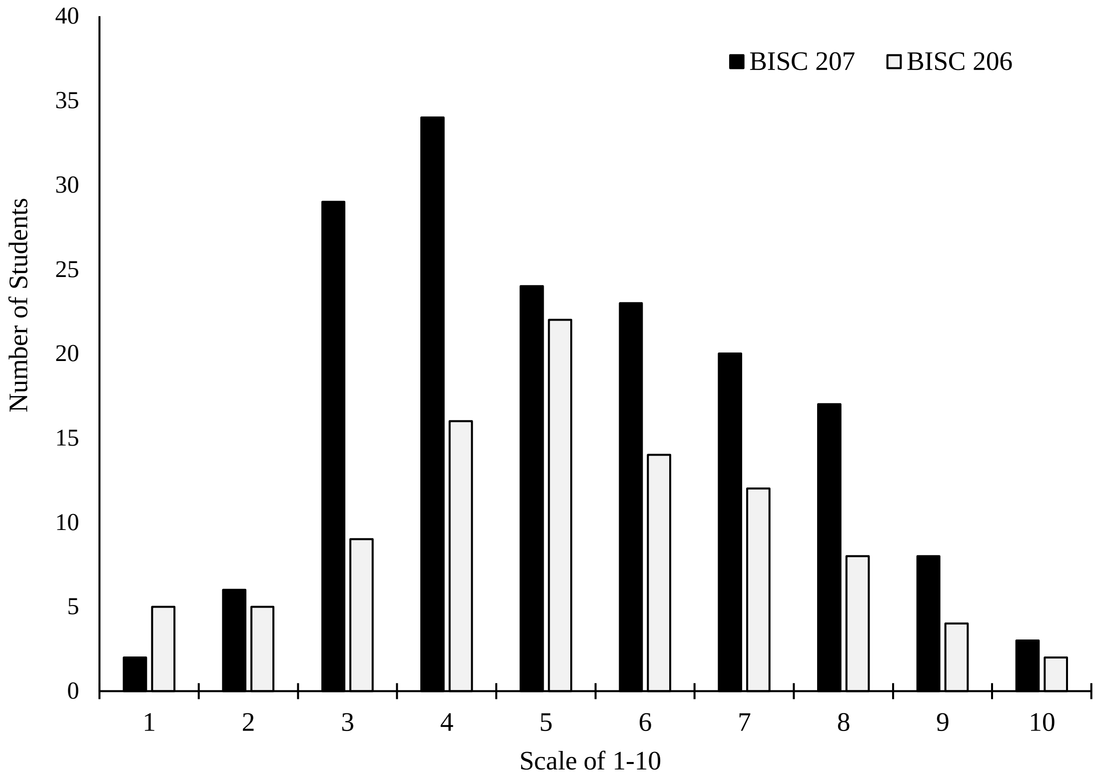

Figure 4. Student ratings of the quality of the pictures taken by students' smartphones through a microscope lens without the use of a microscope adapter with 1 being very low quality and 10 being very high quality.

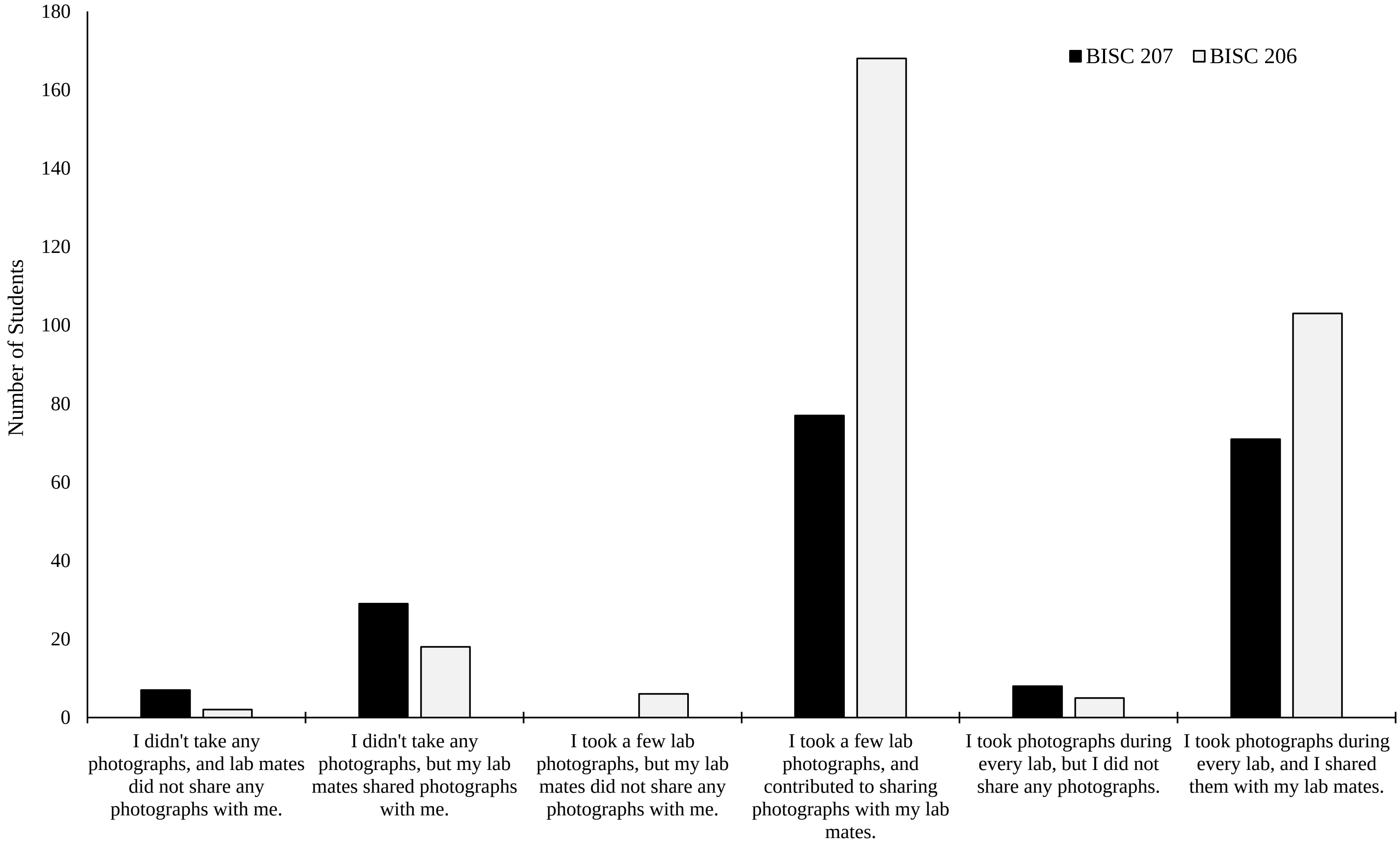

Figure 5. Student responses about how they used the microscope adapters within their lab group.

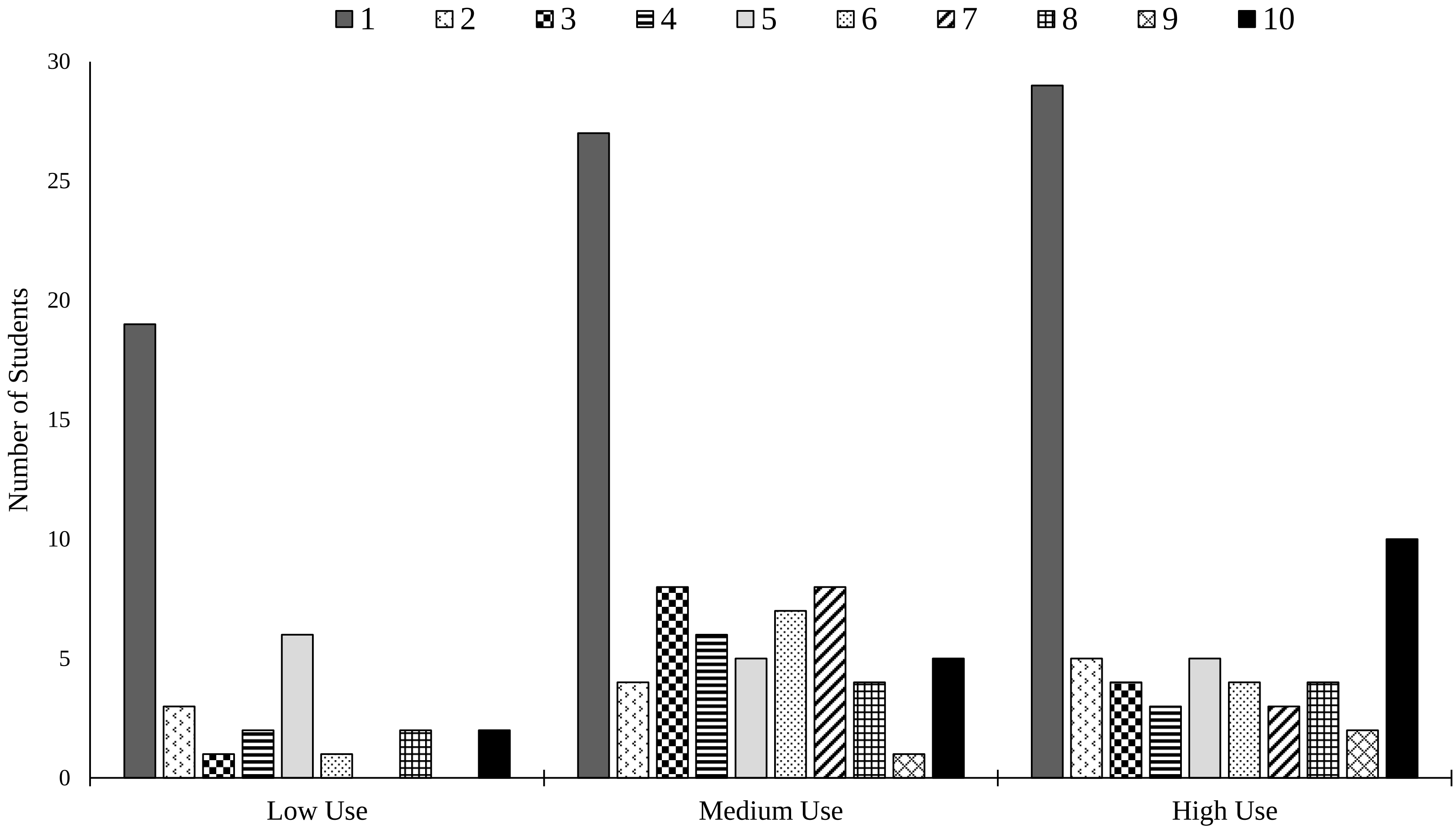

Figure 6a. BISC 207 student ratings of how much they used the microscope adapter along with their smartphone in the laboratories that involved looking at specimens through the microscope with 1 meaning they rarely ever used the adapter and 10 meaning they used the adapter a lot.

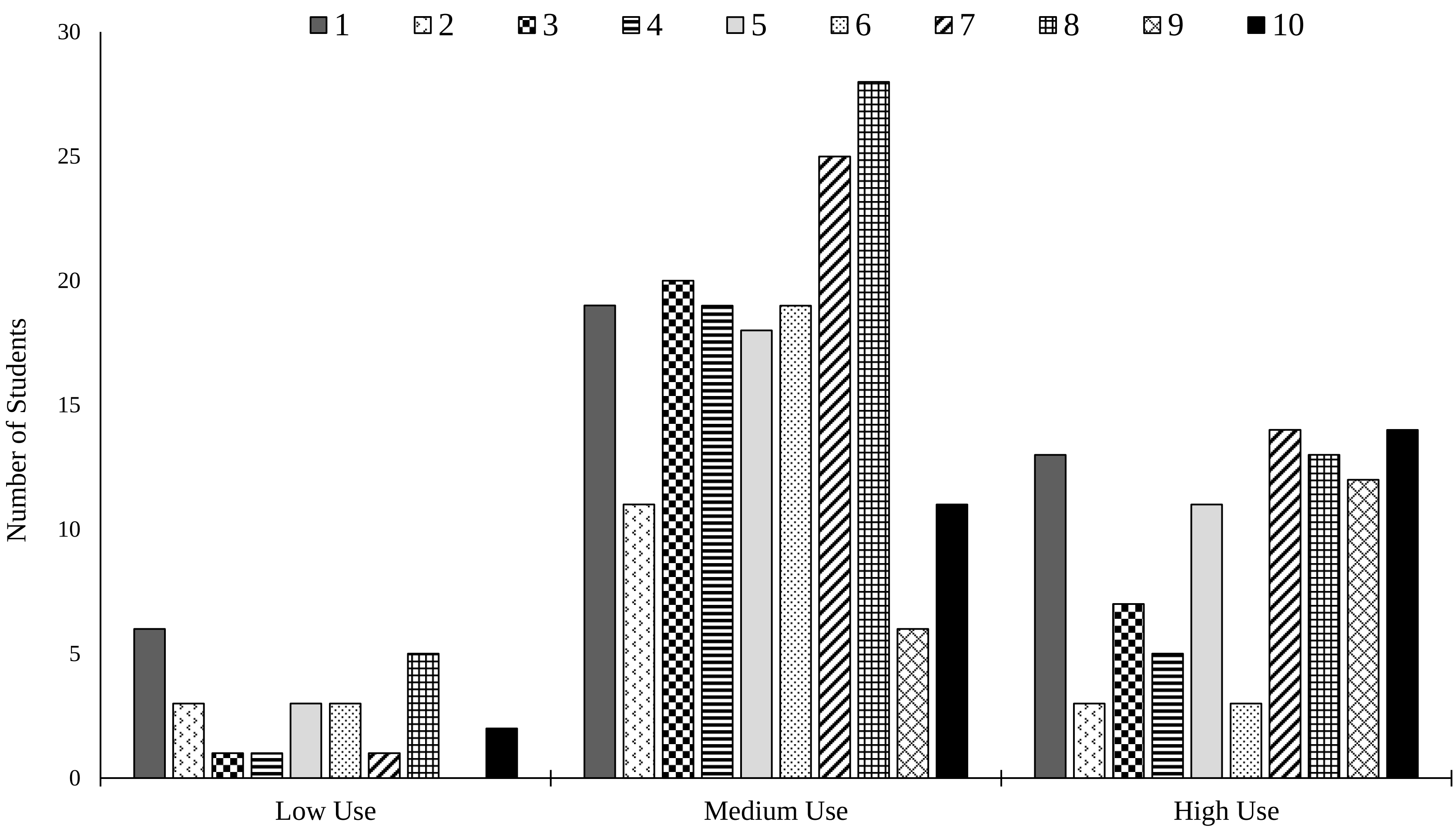

Figure 6b. BISC 206 student ratings of how much they used the microscope adapter along with their smartphone in the laboratories that involved looking at specimens through the microscope with 1 meaning they rarely ever used the adapter and 10 meaning they used the adapter a lot.

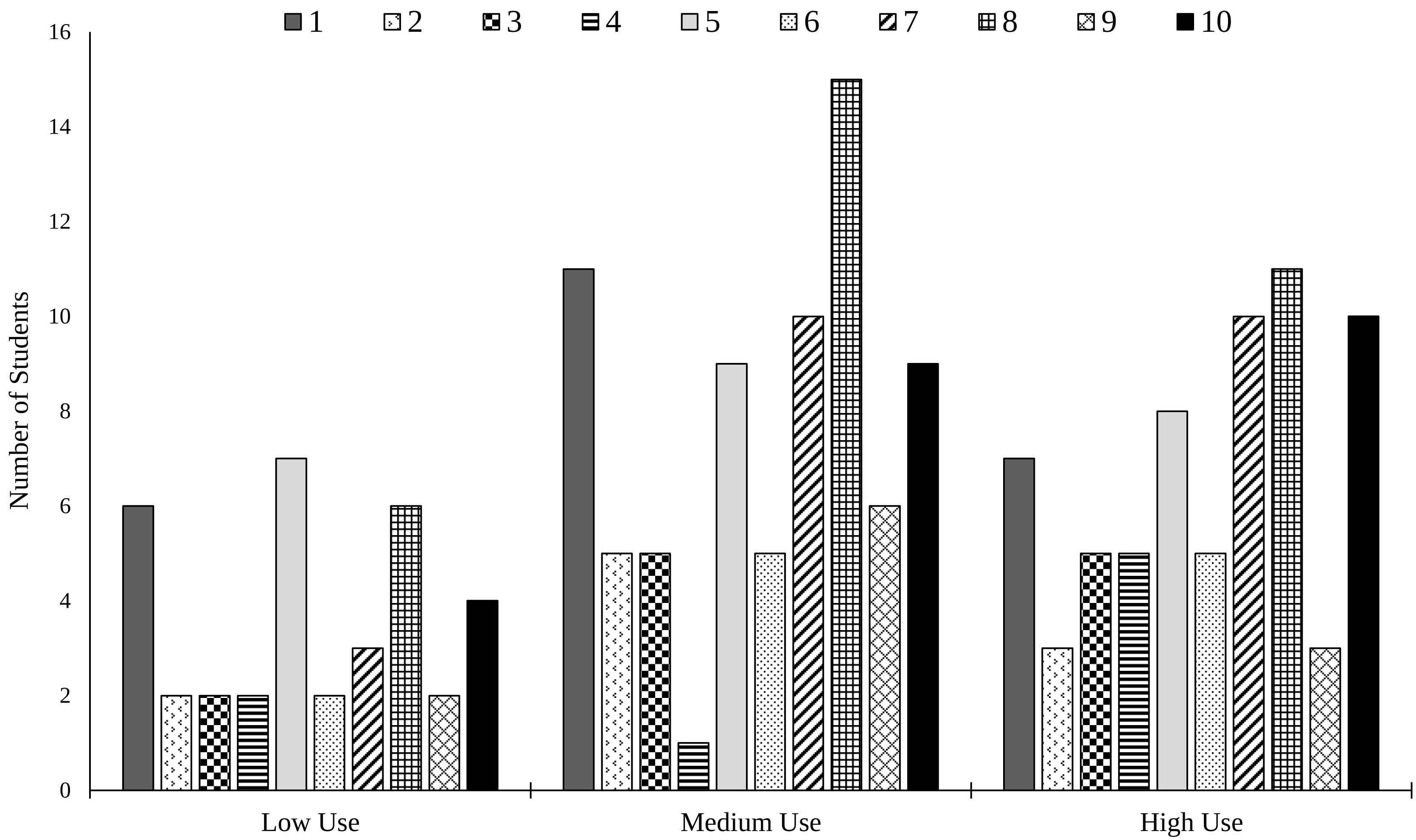

Figure 7a. BISC 207 student ratings of the quality of pictures taken by their smartphone through the microscope lens with the use of the microscope adapter with 1 meaning very low quality and 10 meaning very high quality.

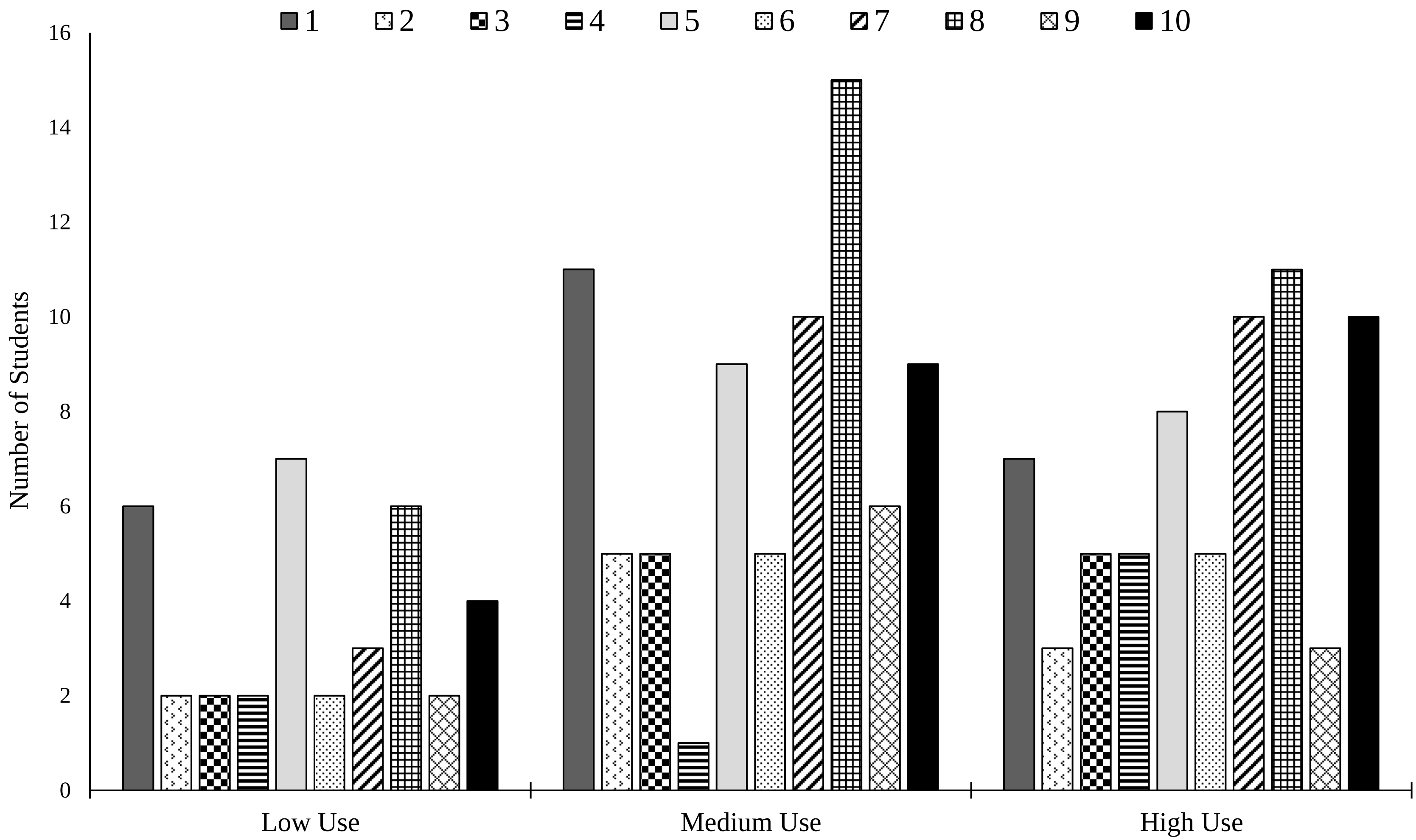

Figure 7b. BISC 206 student ratings of the quality of pictures taken by their smartphone through the microscope lens with the use of the microscope adapter with 1 meaning very low quality and 10 meaning very high quality.

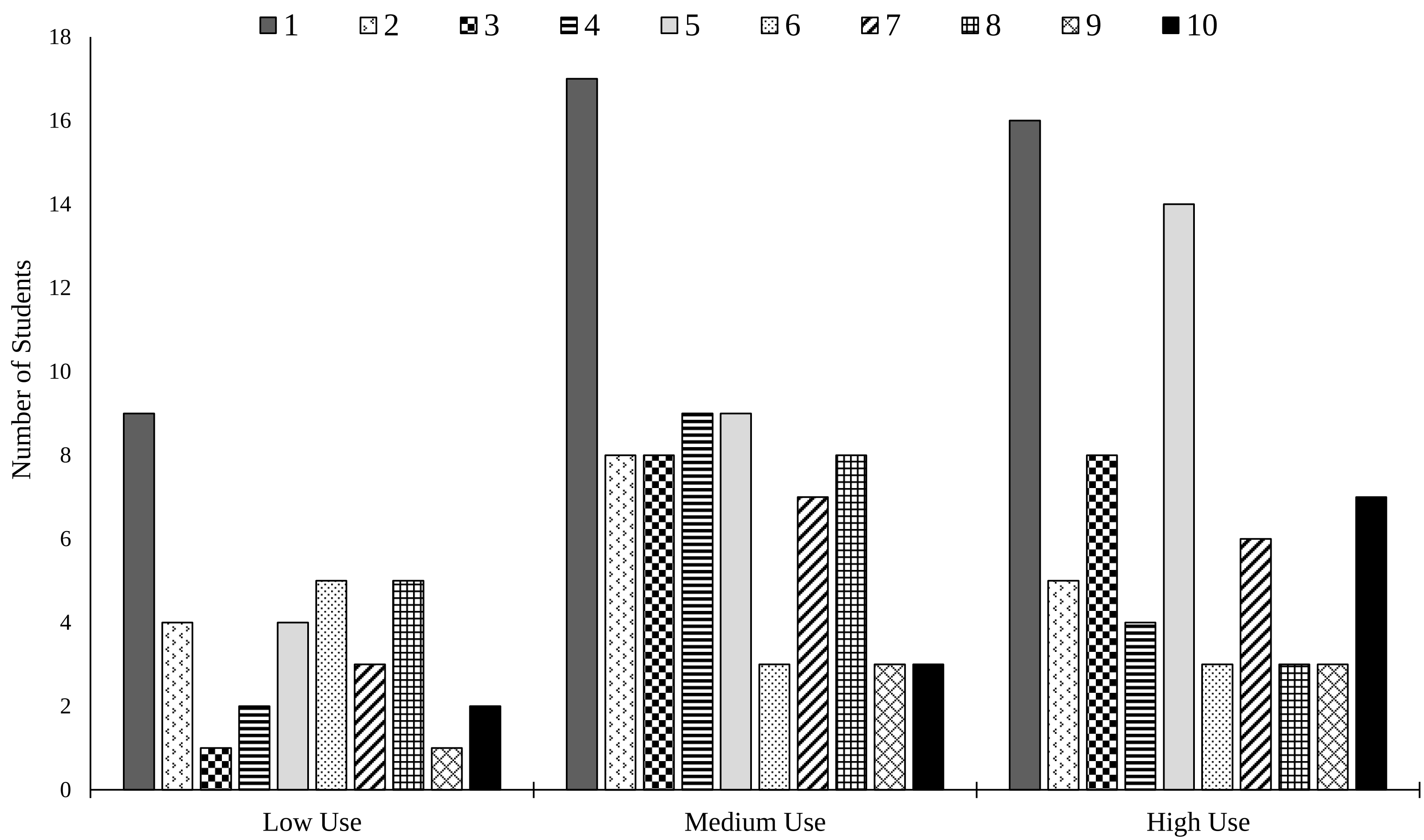

Figure 8a. BISC 207 student ratings of how easy it was to use the microscope adapter with 1 meaning it was very hard to use the adapter 10 meaning it was very easy to use the adapter.

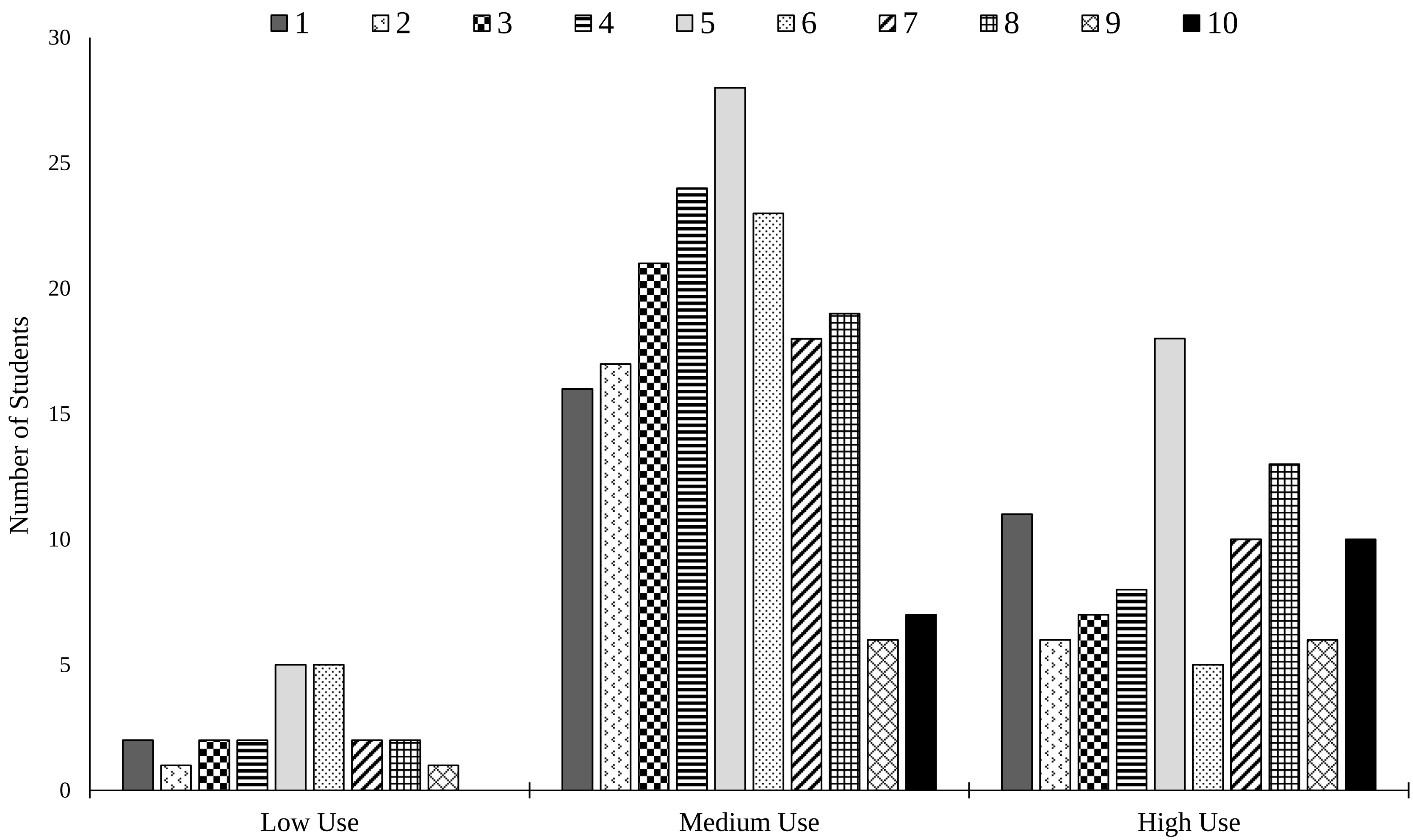

Figure 8b. BISC 206 student ratings of how easy it was to use the microscope adapter with 1 meaning it was very hard to use the adapter 10 meaning it was very easy to use the adapter.

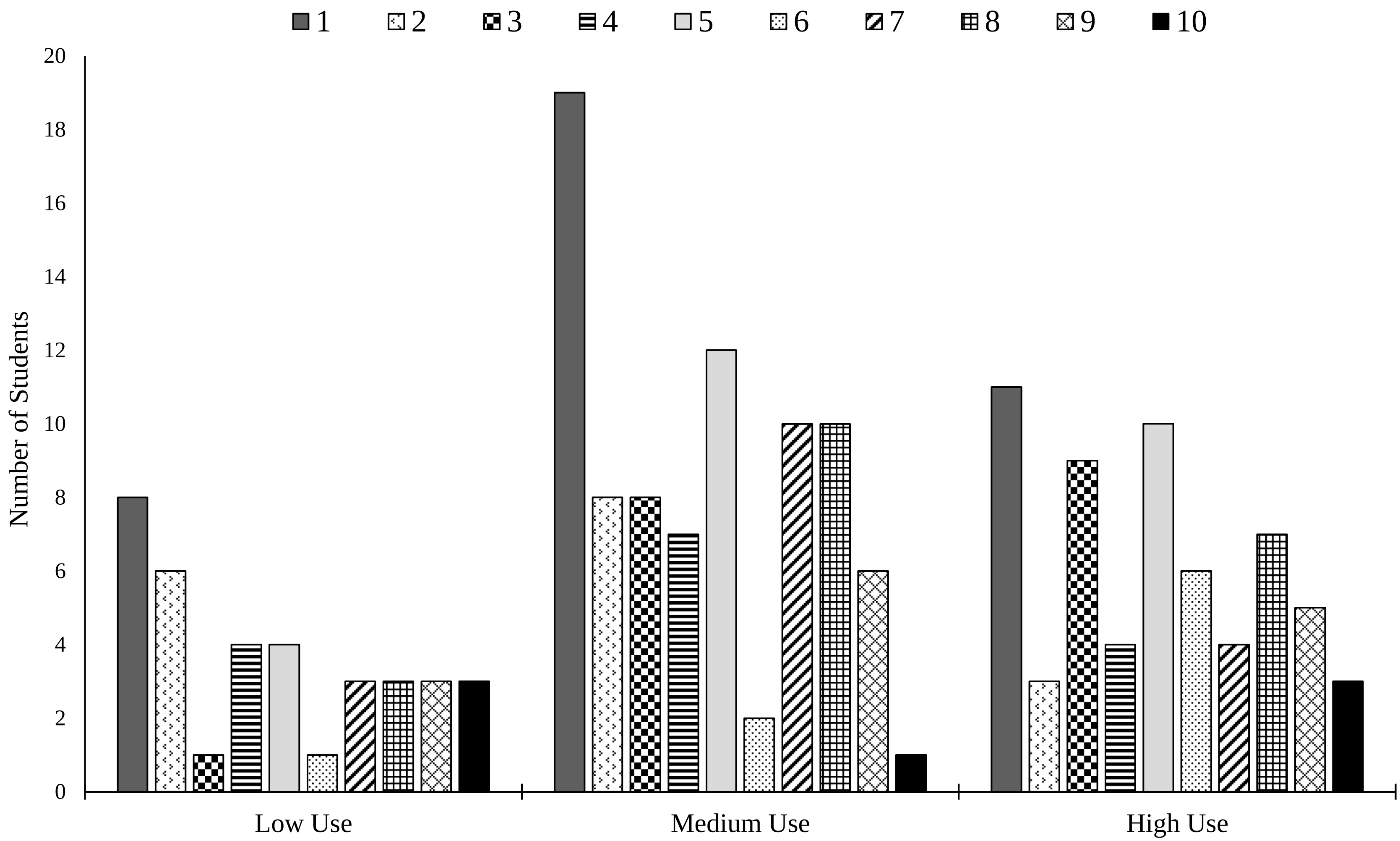

Figure 9a. BISC 207 student ratings of how easy it was to take pictures with their smartphones through the microscope lens with the microscope adapter with 1 meaning it was very hard to take pictures and 10 meaning it was very easy to take pictures.

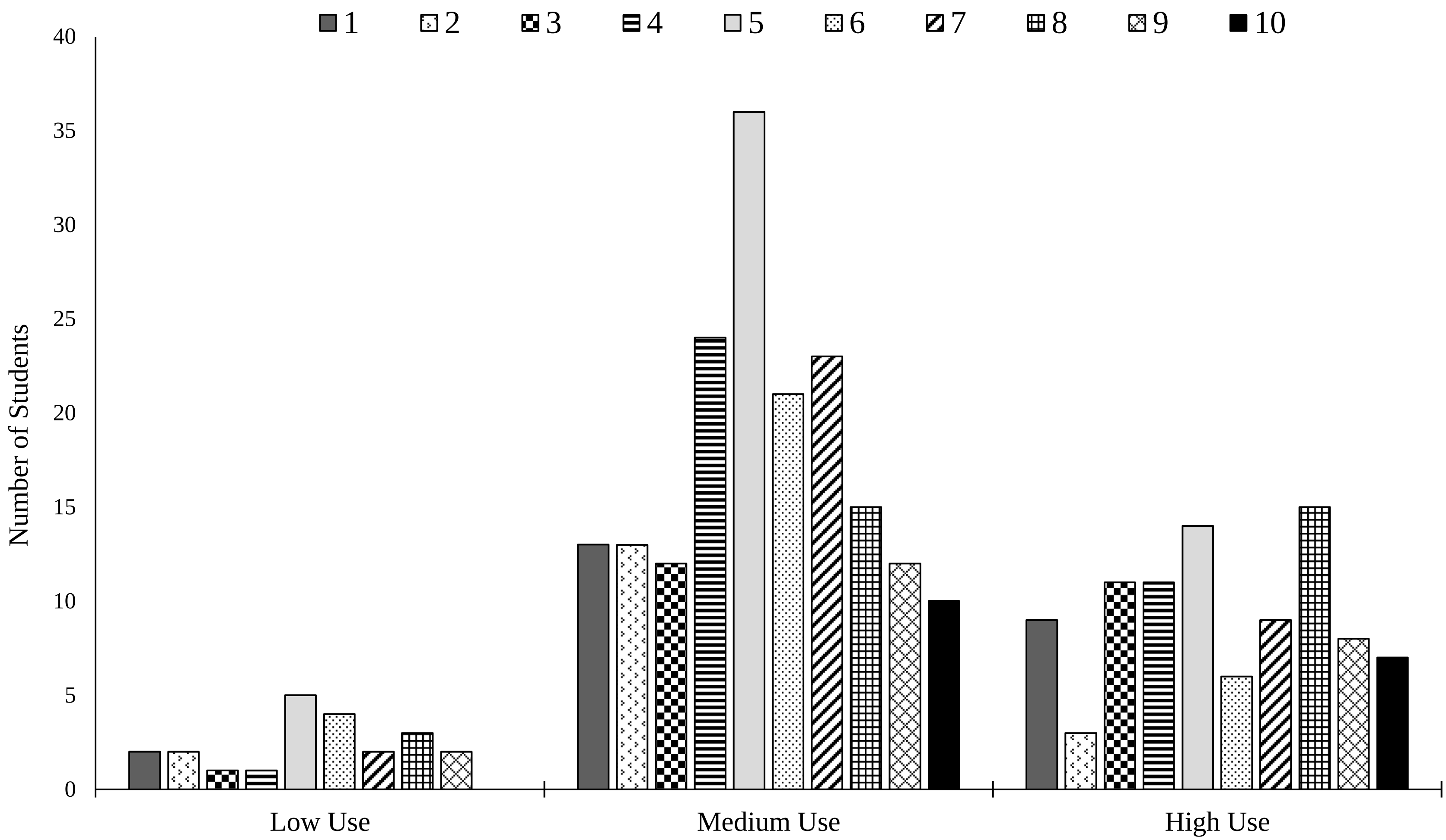

Figure 9b. BISC 206 student ratings of how easy it was to take pictures with their smartphones through the microscope lens with the microscope adapter with 1 meaning it was very hard to take pictures and 10 meaning it was very easy to take pictures.

Appendix A

Microscope Adapter Tips!

Tips on attaching your phone to the adapter:

- https://youtu.be/d7d7FLwCLAI?list=UUhzoX5wnATJ86H6Vt1TuM_g (Times - 0:34 to 1:19 AND 1:33 to 1:57)
- First, line up and lock the phone in place horizontally using the "right phone clamp," making sure that your camera is in-line with the "Circular Camera Cutout" on the adapter. Next, do the same for the vertical plane, locking it in place with the "Bottom Phone Clamp."

Tips on aligning the adapter with the microscope:

- https://www.youtube.com/watch?v=8HdhHvjlhHA&feature=youtu.be (Times – 2:04 to 2:25)
- Once you have fixed and aligned your phone to the adapter, you simply open the claws of the "Optics Clamp" on the adapter by squeezing the spring loaded "Curved Arm Optics Clamp Release." Fit the four clamps over the eyepiece of your microscope and release.
- You may have to adjust the vertical alignment of the phone on the adapter if you can't get it to align correctly. You can also try to attach the adapter to the microscope upside down.

Other tips:

- Focus the microscope first! Afterwards, you can tap on the screen of your phone to do an autofocus with your camera app.
- If the phone and adaptor are wobbly, try rotating the phone (and adaptor) upside down. This change makes the phone's center of gravity more stable.
- You can move the stage of the microscope around (without removing the adapter) to take pictures of different parts of the slide.