The Effects of Smartphones on Multiple Dimensions of Student Learning and Engagement in an Introductory Biology Laboratory

T.E. Prestholdt*, C.L. Weilhoefer, and L.J. Dizney

*Corresponding author
Address for all authors:
The University of Portland,
Department of Biology
5000 N Willamette Blvd
Portland, OR 97203
Email addresses:
TE Prestholdt, holdt@up.edu CL Weilhoefer, weilhoef@up.edu LJ Dizney, dizney@up.edu

Abstract

Faculty at all types of colleges and universities struggle with how smartphone use may enhance or diminish their pedagogy, in part because evidence-based data is lacking for most types of classrooms. Thus, we conducted a thorough investigation in an introductory biology lab course to determine how smartphones affected myriad aspects of student learning and engagement. There were no significant differences in exam scores, the amount of time spent studying, occasions students were off task, or questions asked to the instructor. There were, however, significant differences in several measures of engagement and time management; students allowed to use their smartphones spent 64% less time in peer-to-peer interactions, 46% less time taking notes, 70% less time handling specimens, and 31% less time in lab compared to students who were not allowed to use smartphones. Because these behaviors, in particular peer engagement and note taking, are fundamental skills best developed early in a successful undergraduate career, our results suggest smartphone use should be minimized in introductory biology laboratories.

Introduction

The debate regarding if and when to use smartphones in college classrooms is now almost as common as the dissension of 'breadth vs. depth'. Faculty across all types of colleges and universities struggle with student smartphone use and how it may enhance or diminish their real time or remote pedagogy. Evidence-based data are necessary because the use of smartphones is one of the most unifying and pervasive features of current college students; 96% of US Americans aged 18-29 have not just a cellphone, but a smartphone capable of accessing the internet (Mobile Fact Sheet, 2019). Ten years ago it was predicted that by 2020 mobile phones would become primary means for the internet access for students (Caverly et al., 2009), and it is doubtful current faculty would disagree that this prediction has materialized.

Many studies have demonstrated the benefits of encouraging and integrating smartphone use in large lecture-based classrooms, as their technology has been shown to increase student engagement and participation. Smartphones allow students to access information quickly from a familiar platform, have that information readily available, and can be invaluable to students where English is a second language (Metruk, 2019). Additionally, student response systems such as polling apps provide copious opportunities for immediate and valuable formative and summative assessment (UCISA, 2014; Kent, 2019). In small student-centered courses smartphone technology can also augment student learning; apps that measure anything from leaf shapes (Leafsnap) to Earth's magnetic field (Magnetometer sensor) to QR codes in chemistry labs (Kasperkey's) have been vetted tools for student learning and engagement (William & Pence, 2011; Arabasi & Al-Taani, 2016). Apps can also increase student inclusion (Thomas et al., 2013), and in some cases especially for students with disabilities (Bouck et al., 2016). Moreover, students find smartphones to be convenient, portable, and Earth friendly (Anshari et al., 2017), and many college and university administrators have expanded on these student perceptions and developed their own mobile applications (e.g., MyUT for the University of Texas or UPMobile for the University of Portland). Indeed, smartphones have the potential to reach a wide variety of learning styles and address issues in equity and diversity (Epstein & Bequette, 2013).

There is also a wide body of literature that suggests smartphone use hinders academic performance. Weimer (2014) showed that students who used their devices during class took fewer notes and had poorer recall than students who abstained. Lepp et al.'s (2015) study of 500 undergraduate students showed that students who spend more time on their phone had lower grades, and this was true for phone use both in and out of class. Students can be more distracted from class, specifically from multi-tasking or texting on their smartphones (Grinols & Rajesh, 2014) and their use can increase cheating (Srikanth & Asmatulu, 2013). And perhaps most convincing, Kim et al. (2019) observed first year college students for 14 weeks and found that students spent ~25% of class time distracted by their smartphones, and that those distractions occur every 3-4 minutes and last approximately one minute in duration.

Whether the use of smartphones in the classroom enhances or detracts from student learning appears to be context-dependent. This suggests that determining where (i.e., in which types of classrooms) smartphones would be an enrichment to learning is a key question. In STEM, the hands-on experiences in laboratories are a critical part of their college curriculum. For most biology majors, their college career usually begins with a year introductory biology sequence that exposes students to a broad and comprehensive list of biological topics. The major topics include cellular and molecular biology, genetics, ecology, and evolution. Regardless of the order in which students are exposed to the topics, the sequence serves as a foundation for the content of upper-division coursework (i.e., "you learned this in intro") as well as the starting place to practice skills such as effective note taking, group work, lab protocols, time management, etc. Ideally, students exit their introductory sequence with not only a foundation of knowledge, but with an understanding that learning is a process; it begins with preparing for class, participating in the multi-facets of the class (or lab), continues after class, and is interdigitated with both formative and summative assessment. With that learning process in mind, we aimed to explore how smartphone use affects multiple aspects of learning and engagement for an introductory biology laboratory. We used a unit of the ecology and evolution semester where, in addition to other skills or factors that are shared with the cellular and molecular biology semester, students can use their smartphones to take pictures of specimens. The dependent variables included a wide variety of student behaviors that demonstrated individual engagement with the material, engagement with others, and/or independent study time and time management. We hypothesized that smartphone use would negatively impact all measured aspects of student learning and engagement.

Methods

Data were collected in four sections of Introductory Ecology and Evolution Laboratory (BIO 278 [A-D]), all taught in the same semester by the same instructor (Dizney). This is a one-credit lab taught once a week for three hours, with 20-22 students per section. Classroom observations occurred during a four-week unit on the vertebrate taxonomy and ecology at the University of Portland, both on the main campus and the Franz River Campus. The Franz River Campus is a relatively undeveloped 34-acre river-front site adjacent to the main campus in North Portland, Oregon. The two learning outcomes of this unit are: 1) learning the common and scientific names of the common vertebrate species of the river and main campus and 2) use a dichotomous key to correctly identify mammalian skulls to species. In Week 1 students were exposed to half the material, in Week 2 the students took a practical and engaged in ecological research, in Week 3 students were exposed to the other half of the material, and in Week 4 the students again took a practical (not cumulative) and went into the field to engage in ecological research.

The four lab sections were divided into two treatment groups with two replications each: treatment group 1 was allowed to use their smartphones for Week 1 but not Week 3 (sections A and B) and treatment group 2 was allowed to use their smartphones for Week 3 but not Week 1 (sections C and D). Thus, all students were given (and tested upon) half the material under "smartphone allowed" conditions and half the material under "smartphone not allowed" conditions. Although the definition of smartphone is not universal (Litchfield, 2010), for this study we defined a smartphone to be any device capable of connecting to the internet and taking photographs.

After an introductory lecture, students were read the IRB consent as well as specific instructions for lab. Briefly, a 30-minute PowerPoint presentation was given to remind students of the classification system used in vertebrate biology, to explain and practice using a dichotomous key, to show pictures of skull features used in the dichotomous key made specifically for this lab, and to explain how they would be assessed. At the end of the presentation instructions were given on how the lab would be conducted with the following prompt, "Today is an independent lab, modeled after the labs you will experience in your upper division biology courses. The way you structure lab today is up to you. I am here to answer questions, but you will determine how to go about learning the specimens". The laboratory room was organized into four stations: three with vertebrate specimens and materials (skulls, pelts, taxidermy forms, dichotomous keys, etc.) and one station with a practice practical. Students were free to move through the stations in any order and at their own pace. Throughout the entire lab the instructor was available but did not initiate any contact with students. Upon leaving lab, students self-reported how much time they planned on studying for the practical and the exact time they left lab (moderated by a TA). Although self-reporting is known to have validity concerns, we had no other practical means to collect this data. On each practical there was an ungraded question for students to self-report the actual amount of time spent studying for each practical. These three variables (time in lab and time planned or actually spent studying) were used to gauge time management.

The observer (Prestholdt) used a COPUS-style rubric that recorded individual student behaviors every five minutes (Smith et al., 2017). At each interval, ten possible behaviors were recorded: handling specimens/materials, taking notes/drawing (either on paper or electronically), independently studying/reviewing, engaging in a peer-to-peer interaction about the material, taking pictures of specimens/materials with their smartphone, off-task either on their smartphone or with peers (i.e., gossiping), engaging in a question/discussion with instructor, taking the practice practical, or out of the room. If a student was doing two behaviors at the same time (e.g., handing specimens and drawing), both were recorded (no student was observed doing more than two behaviors at once). To compare means of the smartphone to no-smartphone data t-tests were used. We omitted from statistical analysis students who arrived late, left early, did not take both practicals, or chose to not use a cell phone when allowed ($n = 5$). Ultimately, 71 students were included in the final analysis.

Results

There were no significant differences in practical scores or any engagement metric between lab sections, so data was combined across lab sections for the same treatment. There was also no significant difference between scores for practical 1 and practical 2 (t-test $p = 0.97$) so the data from the two practicals were combined for further analysis.

There were no significant differences between the practical exam scores of students that were or were not allowed to use their smartphones (see Table 1). This was true for comparisons of individual raw scores as well as through comparisons how their practical score deviated from the mean practical score when they used and did not use their smartphones. There were also no significant differences in the amount of time students self-reported that they planned to study or actually studied (both $p > 0.5$, see Table 1). And although both occurred minimally, there were no differences between the number of questions asked to instructor or the occasions students were off-task. Data that were dependent on the physical use of a smartphone (i.e., off task on their smartphones or taking pictures with their smartphones) were all statistically significant (see Table 1).

There were however significant differences in the time spent handling specimens, taking notes, engaging with peers, and the total time spent in class (all $p < 0.0001$, see Table 1). Students allowed to use their smartphones were observed to handle specimens 70% less, engaged in peer-to-peer interactions 64% less, taking notes 46% less, and spent 31% less time in lab.

Discussion

This study investigated aspects of student learning and engagement in an introductory biology laboratory that fall into three broad categories: engagement with the course content (handling specimens, note taking, etc.), engagement with other humans (instructor or peers), and time management and accountability (exams scores, time studying and in lab, etc.). While we hypothesized that the use of smartphones would negatively impact all measured aspects of student learning and engagement in this introductory biology unit, our results suggest smartphones affect only a sub-set in each category.

Our study revealed no differences in time management (outside of class) or grades. This is consistent with other college studies that have found

Table 1

Comparisons of dimensions of student learning when allowed or prohibited from using a smartphone during lab. With the exception of practical exam score, hours studying, and total minutes spent in lab, the mean and standard deviation represent the number of five-minute time intervals students were observed doing that behavior

	no Smartphone use $\bar{X}$ (SD)	Smartphone use $\bar{X}$ (SD)	t-test p value
Practical exam score	81% (15%)	82% (13%)	0.65
Planned hours of studying	2.8 (1.3)	2.7 (1.1)	0.53
Actual hours of studying	2.7 (1.2)	2.8 (1.4)	0.62
Engaging with instructor	0.2 (.5)	0.1 (.4)	0.47
Practice practical station	0.2 (.5)	0.1 (.4)	0.11
Off-task	0.8 (2.0)	0.6 (1.1)	0.11
Studying in lab	0.8 (1.8)	0.4 (.7)	0.07
Handling specimens	2.0 (1.8)	0.6 (.9)	<.0001
Peer-to-peer interactions	1.4 (1.3)	0.5 (.9)	<.0001
Note taking	3.7 (2.3)	2.0 (2.0)	<.0001
Total minutes in lab	47.1 (20.5)	32.7 (16.9)	<.0001
On smartphone	0.1 (.4)	0.6 (.8)	0.0001
Taking pictures on smartphone	0 (0)	1.6 (1.1)	<.0001

no correlation with grades (Martin, 2010; U of NH, 2010; Hochberg et al., 2018). We also found no significant differences with other anticipated negative effects of smartphone use, such as time spent studying in lab ($p = 0.07$), amount of engagement with the instructor ($p = 0.47$), time spent on a practice practical ($p = 0.11$), or amount of time students were off task ($p = 0.11$). However, our study revealed drastic differences in student engagement with the material and with each other; when students were prevented from using their smartphones they were observed handling specimens 30% more, spent 54% more time taking notes, engaging with their peers 36% more, and spent 69% more time in lab. These differences could translate into enormous increases in student engagement over the course of a quarter or semester, and likely impact habits in upper-division coursework.

Perhaps most concerning for our future graduates is the drastic difference in time students spent in lab and engaged in peer-to-peer interactions (~30% and ~65%, respectively). Although these results would likely vary tremendously with other cultural campus norms, if the prevention of device use translates into any increase in student engagement, this should be a major consideration for instructors and how they design and implement their learning objectives.

There are three obvious directions for future work. The first is expand the current study to non-cadaver based anatomy labs in all realms of vertebrate, invertebrate, and botanical specimens. The second is to conduct a parallel study in the other units of introductory biology such as genetics and cellular and molecular biology. The skills of these labs often include microscopy, pipetting, gel electrophoresis, etc., where mandatory personal protective equipment and/or lab safety protocols prohibit the use of smartphones; it would be interesting to design a study in these scenarios that elucidated the role of lab equipment and protocols on peer engagement. The third is to follow two cohorts of students from intro to their upper division courses; do the smartphone habits students acquire as freshman perpetuate throughout their career? That is, it is possible the norms they practice as freshman (compared to sophomores or juniors) have a disproportionate effect on their ability to make good judgement calls about the use of (or abstinence of) their smartphone. Both of these studies would provide additional evidence-based data on what aspects of student learning and engagement are negatively or positively affected by smartphone use.

In conclusion, our study suggests that smartphone use has no effect on grades and time spent studying, but profound effects on some subsets Of student learning and engagement such as peer engagement and note taking. Many college educators find peer engagement and note taking to be critical and fundamental skills that should be introduced and enforced early in the curriculum; peer to peer learning promotes active learning and helps build relationships while note taking helps students focus on material as well as increase their ability to outline or summarize material. Because these skills are often as important, if not more so, for a successful college career and beyond, our study suggests smartphone use should be minimized in some types of introductory biology laboratories.

Acknowledgements

We thank the University of Portland IRB Review Board (IRB00006544) and one anonymous reviewer for very helpful comments and revisions to our manuscript.

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