Can a tablet device alter undergraduate science students’ study behavior and use of technology?

Bioscience Education Research Group, Institute of Membrane and Systems Biology, Faculty of Biological Sciences, University of Leeds, Leeds, United Kingdom

Submitted 13 October 2011; accepted in final form 16 January 2012

Morris NP, Ramsay L, Chauhan V. Can a tablet device alter undergraduate science students’ study behavior and use of technology? Adv Physiol Educ 36: 000–000, 2012; doi:10.1152/advan.00104.2011.—This article reports findings from a study investigating undergraduate biological sciences students’ use of technology and computer devices for learning and the effect of providing students with a tablet device. A controlled study was conducted to collect quantitative and qualitative data on the impact of a tablet device on students’ use of devices and technology for learning. Overall, we found that students made extensive use of the tablet device for learning, using it in preference to laptop computers to retrieve information, record lectures, and access learning resources. In line with other studies, we found that undergraduate students only use familiar Web 2.0 technologies and that the tablet device did not alter this behavior for the majority of tools. We conclude that undergraduate science students can make extensive use of a tablet device to enhance their learning opportunities without institutions changing their teaching methods or computer systems, but that institutional intervention may be needed to drive changes in student behavior toward the use of novel Web 2.0 technologies.

improving classroom teaching; interactive learning environments; pedagogical issues; postsecondary science education; teaching/learning strategies;

STUDENTS ENTERING HIGHER EDUCATION bring with them increasing experience of using technology in the classroom (1a) and have growing expectations about how technology should be integrated into their learning experience at university (2, 24). Many undergraduate students, including those in a physiology discipline, own or will purchase a smartphone, tablet device, or other mobile learning device to use during their time at university (8, 12). However, many universities have not yet fully adapted their systems, processes, and, most importantly, curricula to make full use of such powerful devices (15, 23). Therefore, many students make use of a mobile device as an “add-on” tool to enhance their learning experience, using it wherever and whenever possible (19, 21). This study was conducted to quantify the impact of such a strategy on biological sciences undergraduate students’ learning and study habits. Students were issued with a preconfigured tablet device to use alongside their existing devices and recorded their use of the device and its tools during their taught classes and private study. This study was purposely conducted without altering the curriculum, availability of learning resources, or teaching strategies to illustrate the experience of many students who will enter university campuses with a tablet device where the university has made no particular provision for learners with such sophisticated tools. These data add to the literature of empirical findings on undergraduate students’ actual use of mobile devices and Web 2.0 tools in their day-to-day learning and their perceptions of how a tablet device influences their study strategies. Such empirical findings are essential to help higher education institutions understand how undergraduate students approach learning with the aid of a tablet device and the changes they make to their study habits as a result of the tablet device. These findings will be of particular interest to institutions considering the possibility of offering undergraduate students a tablet device upon registration, either with or without implementing changes to curricula, teaching approaches, and/or university systems. These data also add to the emerging literature investigating the impact of mobile devices on learners’ behavior (19).

A broad range of background literature has been reviewed during the research design, implementation, and analysis stages of this study. While an exhaustive literature review of students’ use of mobile devices, learning resources, and Web 2.0 tools is beyond the purpose of this report, we use selected studies quantifying undergraduate students’ use and perceptions of technology as examples to set the scene for this study. There have been a number of recent studies aimed at quantifying students’ use of technology. In particular, there has been considerable focus on the technological habits of so-called “digital natives,” young people entering university who were born after 1980 (20), who, due to their experience in an increasingly digital and online environment, are purportedly well equipped to make good use of technology in their learning. Studies by Kennedy et al. (11), Conole et al. (2), Selwyn (22), Vogel et al. (26), Corrin et al. (3), Jones et al. (8), Judd and Kennedy (9), Smith and Caruso (24), and Margaryan et al. (12) serve as useful examples of attempts to quantify students’ use of technologies in learning without intervention, but none of them have offered insights into how study behaviors are altered after the adoption of a tablet device. This study aimed to build on previous work by quantifying changes in students’ use of technology when a tablet device was used. Kennedy et al. (11) described a cohort of Australian first-year undergraduate students with varying experience in using technologies that could be used in learning (e.g., blogs, podcasts, RSS feeds, and social networking) but who had a strong desire to use technology in their studies. Conole et al. (2) collected data via online surveys, audio logs, and interviews with United Kingdom undergraduate students to quantify and understand students’ use and perceptions of technology in a variety of disciplines. Conole and colleagues categorized students’ use (and perceptions) of technology into four main groupings: information seeking and handling, communication, assignment

Address for reprint requests and other correspondence: N. P. Morris, Institute of Membrane and Systems Biology, Faculty of Biological Sciences, Univ. of Leeds, Leeds LS2 9JT, UK (e-mail: n.p.morris@leeds.ac.uk).
preparation, and integrated learning. The study (2) described students making use of a wide variety of technologies in personalized, contextualized ways to achieve individual learning goals in all aspects of their studies. Selwyn (22) examined United Kingdom undergraduate students’ use of computers for academic activities and found that information retrieval constituted a major component of their overall activity. The study also found subject-specific variations in use of technology and that female students were more likely to use the internet for information retrieval than male students. Vogel and colleagues (26) reported preliminary findings from an ongoing study to investigate the impact of mobile device applications on students’ learning by providing students with a range of learning tools for use on mobile devices. The study showed encouraging improvements in examination scores for students who engaged with activities on mobile devices but noted reduced student engagement during the course of the trial. The authors (26) concluded that improved learner time management skills and better integration of material into the curriculum would contribute to higher student engagement in future studies. Corrin et al. (3) surveyed undergraduate students on their use of technology in “everyday life activities” and “academic activities” and found that students used technology more in everyday life than for academic purposes and that the use of some common Web 2.0 tools (e.g., podcasts, blogs, and RSS) was generally low. Jones et al. (8) conducted a survey study across five United Kingdom universities and found correlations between students’ social and academic use for newer technologies (e.g., instant messaging and internet telephony). The study (8) also showed that students made extensive use of some technologies to support their studies (e.g., e-mail and virtual learning environment (VLE)), often beyond their university’s expectations, but did not show homogenous characteristics as a cohort. Judd and Kennedy (9) examined the use of technology by Australian medical and biomedical sciences students over a 5-year period by collecting data directly from personal computers (PCs) used by students, focusing on four key academic areas: information seeking, communication, university services, and information sharing. The study (9) found that students made extensive, and increasing, use of information seeking tools (e.g., Google and Wikipedia) and social networking tools but low use of Web 2.0 technologies (e.g., blogs, YouTube, and social bookmarking), echoing other studies. Smith and Caruso (24) described findings from the 2010 Educause Center for Applied Research study of United States undergraduate students’ use of technology, devices, and learning tools. The results showed increased use of smartphones and tablet devices, confidence with searching effectively for information, and high use of social networking tools. However, only ~20–40% of respondents reported using podcasts, wikis, blogs, social bookmarking, and microblogging to collaborate on academic courses (24). Margaryan et al. (12) used a qualitative and quantitative approach to study Australian engineering and social work students’ use of technology, recreationally and for academic purposes. The study (12) found that students made little use of newer technologies (e.g., blogs, podcasts, and YouTube) and tools (e.g., handheld devices) for learning and concluded that technology use was influenced by age, subject, and the university’s promotion of technology use for learning.

Overall, these studies have described a generation of students with greatly varying competence with technology, use of technology for learning, and, in particular, knowledge of how technology can be best used in a learning environment. While Prensky’s predictions (20) about digital natives may be justified for social or everyday activities, there is a growing body of empirical research evidence that contests their ability to make good use of technology and mobile devices in learning environments, suggesting a need for institutions and academic teachers to provide leadership and continued training in how technologies can be translated from the social sphere into “learning technologies” (10). Also, students’ use of Web 2.0 technologies appears rather low in higher education, while very prevalent in social spheres, which is rather perplexing given the potential usefulness of many of these interactive and content-rich tools. It is therefore becoming important to understand if, and how, mobile devices can facilitate the transition of Web 2.0 tools into useful learning tools for students. Furthermore, there is a growing need to identify the critical factors affecting learners’ satisfaction with mobile devices as learning tools, as has been conducted for e-learning systems (25). A number of factors critical for e-learning are likely to also be relevant to use of mobile devices, including the learner dimension (learner attitude, learner computer anxiety, and learner internet self-efficacy) and the technology dimension (technology quality and internet quality) (25).

Previous studies have quantified students’ use of technology, tools and devices at a single point in time, but there is little empirical evidence measuring students’ changes in behavior as a result of intervention with a mobile device. The aims of this study were to provide quantitative and qualitative data on the effect of providing undergraduate biological sciences students with a tablet device on their use of technology for learning and their study behaviors. The research hypotheses were as follows: 1) students provided with a preconfigured tablet device will develop altered study behaviors, particularly in their use of devices and tools for learning; and 2) students provided with a preconfigured tablet device will make increased use of Web 2.0 technologies (e.g., podcasts, blogs, wikis, and YouTube) to supplement their learning. The study was designed in order that changes in students’ use of devices, tools, and technologies could be quantified and analyzed statistically, in addition to students’ views about the ease of use and effectiveness of a mobile device for learning.

METHODS

Study design. This study was designed to include control and trial periods across a single academic year: the control period was 10 wk in the first semester (October to December) and the trial period was 10 wk in the second semester (February to April). Ethical approval for the study was obtained from the University of Leeds Biological Sciences Ethical Review Committee. Fifty participants were recruited to the study after e-mail and poster advertising targeted to all Faculty of Biological Sciences undergraduate students. Students interested in participating in the study were invited to an information session, where they were told about the study design, requirements, and incentives. All participants were provided with written information about the study and completed written consent forms before the study commenced. All participants were required to complete an initial baseline questionnaire at the beginning of the control period containing Likert-style questions to capture information about their demographics, prior use of technology and devices, and perceptions about technology. All participants were required to complete the same questionnaire at the end of the study. Throughout the control and trial
periods, all participants were required to complete a numerical study habits questionnaire twice during each week (on different days), which recorded the time spent on activities and using various tools (see the Supplemental Material for the study habits questionnaire). Participants completed the questionnaires electronically via the institutional VLE; e-mail reminders were sent to participants to complete the study habits questionnaire on preallocated days. Participants were required, and regularly reminded, to only report activities associated with learning and not to report any social uses of tools or devices. Both the baseline questionnaire and numerical study habits questionnaire were designed with reference to similar studies in the literature (8, 9, 24) and evaluated by a range of e-learning experts and modified in accordance with their comments before use with study participants. In the trial period, 25 participants were issued with a preconfigured Apple iPad (the iPad participants). The remaining participants (non-iPad participants) were not issued with any devices but were asked to continue with the study throughout the trial period. The iPad participants were randomly selected with reference to the following criteria: (1) year of study (equal numbers of students in levels 1, 2, and 3 were selected) and (2) prior familiarity with technology (participants with a range of prior familiarity of technology were selected, using responses from the baseline demographic questionnaire). iPad participants received their device after completion of an additional consent form and attendance at a 2-h training session where they received basic training on using and configuring the iPad, along with suggested uses for the preinstalled applications (apps). Participants were given instructions on how to create an iTunes account (if required) and how to install additional apps and content on the device (if required). All participants were incentivized to complete the study habits questionnaire by the reward of printer credits for each successfully completed questionnaire. iPad participants were required to attend two focus group meetings during the trial period and to attend one-to-one meetings with the researcher, as required, to backup the device.

Device configuration. Twenty-five Apple iPads (16Gb, wifi, and 3 G) were purchased from Apple. Each iPad was set up with a unique username, and iTunes accounts were credited with gift certificates to allow for the installation of paid apps on the device. All iPads were configured with the same apps; additional subject-specific apps were also installed on iPads according to each iPad participants’ degree program (data on usage of subject-specific apps were not collected). All iPads were setup with a passcode and a MobileMe account. Participants were provided with the iPad, a cover, and a charger for a 3-mo period.

Data analysis. Data were manipulated, organized, and graphed in Microsoft Excel. Statistical analysis was conducted using SPSS (version 16.0). Data from the numerical study habits questionnaire were quantified, and average responses for each participant were obtained from all of the study habits questionnaires completed. All data are expressed as means ± SD. When participants were required to select a time, such as 1–2 h, the average time was used for analysis (i.e., 90 min in this example). If participants did not complete questions within the study habits questionnaire, they were removed from the control and trial period data set. All data were anonymized before analysis. Likert-style questions were converted to numerical scores for statistical analysis using χ²-tests. Likert-style questions were assessed for reliability using Cronbach’s α reliability test. Significance was set at the 95% level for all statistical tests ($P < 0.05$ was considered significant). All data were assessed for normal distribution using a Kolmogorov-Smirnov test. Where data were normally distributed, paired $t$-tests were used to assess differences between participants’ responses in the control and trial periods. When differences between unrelated populations of normally distributed data were tested, independent Student’s $t$-tests were used. Where data were not normally distributed, the Wilcoxon ranked-signs test was used to compare participants’ responses in the control and trial periods and the Mann-Whitney $U$-test was used to test for differences between unrelated, non-normally distributed populations.

The results should be treated with caution due to the following factors. First, the sample size of students reporting use of technology is small, although repeated responses were obtained from each participant, increasing the reliability of each participant’s responses. Second, participants volunteered for the study based on their individual motivations; as such, they were a self-selecting group of participants and may not be fully representative of the undergraduate population. Finally, participants self-reported the frequency and time spent using technology throughout the study and may have performed some tasks simultaneously. A previous study (4) has shown that self-reported data on computer use is not always reliable.

RESULTS

Participant demographics. Forty-eight undergraduate students were recruited to the study. There were 27 women and 21 men. Participants ranged in age from 17 to 45 yr; the mean participant age was $21.6 \pm 5.0$ yr. Participants were at different stages of their undergraduate degree; there were 18 first-year (level 1) students, 13 second-year (level 2) students, and 17 third/fourth-year (level 3) students. Participants were recruited from within the Faculty of Biological Sciences of the University of Leeds from a wide range of bioscience-related degree programs (including neuroscience, human physiology, pharmacology, medical sciences, biology, biochemistry, and microbiology). All participants were full-time students attending a range of taught classes (lectures, tutorials, seminars, and practicals). Twenty-five participants received iPads. Of these, nine participants were first-year students, seven participants were second-year students, and nine participants were final-year students (third or fourth year). The average age of the iPad participants was $21.6 \pm 4.2$ yr (year of birth between 1972 and 1992; median year of birth: 1989). There were 10 male students and 15 female students. One iPad participant withdrew from the study during the trial period, and, therefore, all data from that participant were removed from the analysis. iPad participants ($n = 24$) completed a total of 388 study habits questionnaires (average of 16 per participant) in the control period (an 80% response rate) and 272 questionnaires in the trial period (average of 11 per participant, a 57% response rate). There was poor compliance with completing the study habits questionnaires among the non-iPad participants in the trial period, so their data have not been included within this study.

Devices owned/used for learning. At the beginning of the study, iPad participants reported owning an average of 4.3 electronic devices that could be used for learning ($n = 24$), including laptops, desktop computers (PCs), mobile telephones, smartphones, portable media devices, voting handsets, tablet devices and eReaders. All participants owned a laptop computer or netbook and 96% used it (or planned to) for studying (Fig. 1). Only 21% of participants ($n = 5$) reported owning a desktop computer (PC), and, of these, only 13% used it (or planned to) for studying. Twenty-two participants (92%) reported owning a mobile telephone or smartphone (e.g., iPhone, Android device, or Blackberry). Of the two participants that didn’t own a mobile telephone/smartphone, one said they owned a device not on the list. Of mobile telephone/ smartphone owners, 42% used it (or planned to) for studying.

---

1 Supplemental Material for this article is available at the Advances in Physiology Education website.
Seventeen participants (71%) reported owning a portable media device (e.g., iPod or similar), but only 21% used it (or planned to) for studying. Ownership and/or usage of other devices [e.g., personal digital assistant (PDA), tablet devices, and eReaders] was low among the participants.

At the end of the study, iPad participants were asked to complete the same questionnaire (n = 24). Participants reported a significant reduction in the use of a laptop computer or netbook for learning (down from 96% to 75%, P < 0.05, Pearson \( \chi^2 = 4.2 \); Fig. 1). Participants also reported reduced use of PCs, mobile telephones/smartphones, and portable media devices, but these changes were not significant (Fig. 1).

iPad participants reported high levels of competence and confidence with use of the internet (96% agreed), use of software applications (74% agreed), and information literacy (91% agreed). Ninety-two percent of participants agreed with the statement that technology enhanced learning enhanced their education (Cronbach’s \( \alpha \) for question reliability: 0.78). There were no significant differences between level or sex in participants’ responses, but there was an overall tendency for women to report lower confidence and competence with technology and software applications. At the end of the study, iPad participants’ responses to the same questions increased but not significantly.

Use of online learning resources and Web 2.0 tools. At the commencement of the study, iPad participants (n = 24) reported their prior use of online learning resources and Web 2.0 tools via a baseline questionnaire. Data from the questionnaire showed wide variability in use for common tools. The vast majority of participants had previous experience with online search engines (100% used previously), online journal articles (83%), and online dictionaries/thesaurus (88%), but less than half of participants used online journal articles and dictionaries/thesaurus at least once a week. Common Web 2.0 tools were less well used by participants: wikis had been used (reading and editing) previously by 79% of participants, but were only used regularly (more than once a week) by 38% of participants. Discussion forums had been used (reading and editing) by 67% of participants, but were only used regularly by 17%. Similarly, blogs had only been used (reading and writing) by 50% of participants and were only used by regularly by 4%. Fifty percent of participants reported using podcasts as learning resources previously, with 4% using them more than once a week. Online content provided by academic publishers was also used infrequently: only 45% of participants reported using it previously, with no students reporting using it regularly. Fifty-four percent of participants had used audio recording tools previously, but only 17% reported using them more than once a week.

Participants completed the same questionnaire at the end of the trial period. iPad participants made similar use of online search engines (100% used frequently) and use of other learning resources and Web 2.0 tools had changed in some areas. In particular, participants reported using literature search engines (\( P < 0.05, \chi^2 = 16.3 \)), wikis (\( P < 0.05, \) Pearson \( \chi^2 = 14.3 \)), podcasts (\( P < 0.05, \) Pearson \( \chi^2 = 13.7 \)), and audio recordings (\( P < 0.05, \) Pearson \( \chi^2 = 4.1 \)) more frequently.

Overall usage of the iPad. iPad participants received devices preconfigured with ~30 apps for educational use and received training and advice on how to make the best use of these for studying. The proportion of time spent on individual apps was calculated from the times recorded by iPad participants in the study habits questionnaire (n = 24; Fig. 2). The most heavily used app was Soundnote (26% of total time spent on apps), which allows note taking and simultaneous, synchronized audio recording, followed by the internet browser Safari (24% of total time; Fig. 2). E-mail (7%), the Google app (5%), and Facebook (4%) were the next most popular apps. Usage of apps varied by level (Fig. 2), but for most apps showed broadly similar patterns to overall app usage. However, some apps were more popular with level 1 and 2 students: for example, word-processing, course note, and eBook apps. iPad participants reported spending an average of 57.2 ± 11.4 min/day on Soundnote. This varied slightly by level, with level 2 students using the app for longer than students in the other levels. By comparison, e-mail was used for an average of 17.3 ± 4.3 min/day, for similar times between levels. PubMed on Tap, an app to search the PubMed bibliographic database for journal articles, was used for an average of 4.6 ± 3.7 min/day and was used predominately by level 2 and 3 students. The total time spent on apps per day (Fig. 2) was calculated at 232.9 ± 47.5 min (over 3.5 h/day), with level 2 students reporting the highest
app usage (266 ± 75.4 min), followed by level 3 students (224.3 ± 69.7 min) and level 1 students (206.9 ± 47.3 min). App usage was relatively stable over the 10-wk trial period (Fig. 2), with a slight (but nonsignificant) dip in usage around the middle of the trial.

When completing the study habits questionnaire, iPad participants were asked to describe their usage of the iPad in a sentence. There were 150 responses to this question from 21 iPad participants (a response rate of 31%). Responses were grouped into categories using keywords (e.g., names of apps and activity), and 207 keywords were recorded. “Soundnote” (which included all references to recording lectures or audio) accounted for 32% of responses, “search” (which included all reference to searching the internet, looking things up, etc.) accounted for 13% of responses, and “researching papers” (which included all references to searching for, reading, annotating, or using research papers) accounted for 9.7% of responses. Other keywords, accounting for between 5% and 10% of responses, were “dictionary,” “podcasts,” “VLE,” and “notes.” The majority of responses reported usage of a single app or activity, but some responses gave detailed accounts of participants’ use of the iPad. A selection of representative responses is included below:

Searching for papers, reading papers, looking up definitions using safari, using iPod whilst working

General use for calculator, converter, dictionary, wiki, it is good to have all of these in one place instead of carrying around each individual item. Listening to podcasts from itunes U. Using soundnote to record and listen to my lectures, and then dropbox to save them.
I like using the iPad to look at documents for tutorials as it is easier to read from than a computer screen and more portable. Recently I’ve been using the calendar to keep track of classes and I love the way a little bubble with the lecture (module code) and room number comes up 10 mins before each lecture. I use the dictionary in lectures to look up words used that I don’t know and record all my lectures on it. I’ve recently been listening to them as I walk to and from home which is great as you don’t need the internet.

Revolutionary, this has changed the way I approach a class, I feel totally prepared as, I get the lecture slides without having to print them, take notes, record, reference and if necessary look things up, all in the palm of my hand... WOW

I was busy yesterday with lab work so I didn’t get a chance to use it as much, I don’t bring it into lab due to a fear of it getting broken. I used it mainly to watch videos on youtube, i.e., looking for lectures, or videos explaining biological functions.

Got 60 of my dissertation papers on Goodreader. Much lighter than having paper copies, but can still mark them up in a similar way.

I use the iPad for accessing course notes, emailing, internet browsing, soundnotes for lectures and iBooks for downloading course text web version.

Apart from typing essays and lab reports this device is pretty much all I need. It desperately requires a flash plugin and USB functionality though.

At the end of the study, iPad participants were asked to report the three most useful apps for enhancing study, in their experience. Participants were asked to exclude Safari, e-mail, and calendar apps when making their choices. Thirty-six percent of participants chose Soundnote, followed by PubMed (11%), Goodreader (9%), Dropbox and Biochemistry Reference (5%), and Dictionary, Docs To Go, TED, iTunesU, and Wikipanion (4%).

During the study, participants were asked to report any new apps installed on the device and any content downloaded to the device. Most new apps added to the devices were discipline specific and provided information or practice quizzes. A few generic apps were also added to some devices, including Dragon Dictate (a voice recognition tool) and Mendeley (a reference management tool). Content added to devices was mainly book chapters, journal articles, academic podcasts (from iTunesU), and videos.

Use of the iPad in taught classes. Overall, iPad participants (n = 24) used the iPad in taught classes for an average of 83 ± 53.9 min/day compared with other devices (e.g., PC, laptop, smartphone, or portable media device), which were used between 1 and 13 min/day (see Table 2). iPad participants reported that the iPad constituted 63.3% of their total device usage in taught classes; by comparison, laptops constituted 10.5% of the total device usage. iPad participants reported significantly reduced usage of PCs and smartphones in taught classes during the trial period compared with the control period (P < 0.05 by Wilcoxon signed-ranks test, n = 24; Table 2).

Table 2. Participants’ reported use of devices for learning in taught classes during the control and trial periods

<table>
<thead>
<tr>
<th></th>
<th>Control period</th>
<th>Trial period</th>
<th>Time Spent Using the Device in the Taught Classes, %</th>
<th>Significance (P Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laptop</td>
<td>14.8 ± 24.8</td>
<td>9.1 ± 14.1</td>
<td>10.5</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Personal computer</td>
<td>22.3 ± 25.6</td>
<td>13 ± 27.4</td>
<td>9.3</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>iPad</td>
<td>0</td>
<td>83 ± 53.9</td>
<td>63.3</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Smartphone</td>
<td>3 ± 6.2</td>
<td>0.7 ± 2.2</td>
<td>2.6</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Portable media device</td>
<td>5.3 ± 12.5</td>
<td>5.7 ± 15.4</td>
<td>3.3</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

Values for reported time are means ± SD (in min); n = 24 participants. P < 0.05 indicates a significant difference between control and trial periods by Wilcoxon signed-rank test.
equivalent between control and trial periods (Fig. 3). iPad participants reported a reduced, but not significant, total time in taught classes between control (147.3 ± 63.9 min, n = 23) and trial (123.5 ± 42.5 min, P > 0.05, paired t-test, n = 23) periods. Looking at individual teaching activities, participants reported similar time spent in lectures (control period: 81.1 ± 33.3 min and trial period: 76.8 ± 32.8 min, P > 0.05, paired t-test, n = 23), practicals (control period: 17.6 ± 19.1 min and trial period: 13.7 ± 16.7 min, P > 0.05, paired t-test, n = 23), tutorials (control period: 7.3 ± 6.9 min and trial period: 9.6 ± 9.2 min, P > 0.05, paired t-test, n = 23), and computer classes (control period: 3.7 ± 5.6 min and trial period: 3.3 ± 7.6 min, P > 0.05, Wilcoxon signed-ranks test, n = 23). In taught classes, iPad participants mainly used the iPad for audio recording (67.7 ± 56 min, 50% of total usage), creating or editing Microsoft Office software (e.g., Word, Excel, and PowerPoint, 33.1 ± 47.2 min, 16.4%), viewing VLE resources (11.6 ± 19.7 min, 11%), viewing e-mail/VLE announcements (4.7 ± 7 min, 3.9%), and conducting online searches (5.1 ± 6.7 min, 3.1%). Other activities, including use of web resources, online journals, statistics tools, podcasts, and wikis, accounted for the remaining 16% of total tool usage in taught classes.

Use of the iPad during private study. iPad participants reported the time spent in a variety of private study locations during control and trial periods (Fig. 3). The total reported private study time did not change between control (149.4 ± 96.0 min) and trial (143.0 ± 87.4 min, P > 0.05, paired t-test, n = 23) periods. iPad participants reported spending significantly longer studying in the library in the trial period (31.8%, 28.7 ± 25.6 min, P < 0.05, paired t-test, n = 23). They also reported spending less time studying in private accommodation in the trial period (40%, 57.2 ± 51.9 min) compared with the control period (53%, 79.1 ± 58.5 min, P < 0.05, paired t-test, n = 23). Reported private study time did not vary between control and trial periods for private study in computer clusters (control period: 25% and trial period: 23.3%, P > 0.05, paired t-test, n = 23) or other campus locations (control period: 3% and trial period: 5%, P > 0.05, paired t-test, n = 23).

iPad participants reported the proportion of time spent using devices during private study. In the control period, iPad participants (n = 24) reported using laptop (or netbooks) for 34% of the time and PCs for 31% of the time. Other devices, such as mobile devices (e.g., tablets and PDAs), smartphones/mobile telephones, and portable media devices (e.g., iPod), were used between 7% and 18% of the time. During the trial period, iPad participants (n = 24) reported a large shift in device usage toward mobile devices (from 7% to 22%) and reductions in the use of laptops (27%), PCs (28%), and smartphones/mobile telephones (18%).

iPad participants reported time spent using learning resources and Web 2.0 tools during private study in three categories: reading activities, writing activities, and interactive activities. The average time that iPad participants spent on these activities during the trial period was analyzed and compared with their responses during the control period (Table 3). iPad participants showed increased use of hard copies of journal articles in the trial period (7.2 ± 12.5 to 17.3 ± 20.5 min, P < 0.05, Wilcoxon signed-ranks test, n = 22 participants). There was no change in iPad participants’ reported use of online journal articles during the trial period (24.5 ± 29.5 to 26.3 ± 27.9 min, n = 22). However, iPad participants reported a reduction in the use of printed learning resources in the trial period. In the control period, participants reported using printed learning resources for an average of 14.9 ± 19.4 min (n = 24 participants) compared with an average of 9.2 ± 19.2 min in the trial period, a significant reduction of 38.3% (P < 0.05, Wilcoxon signed-ranks test, n = 22 participants). iPad participants reported reduced use of hardcopy books during the trial period (Table 3), but there was very little reported use of online books or eBooks in the control or trial periods (average of <1 min). iPad participants reported a small increase in the use of wikis during the trial period, but this change was insignificant (Table 3). iPad participants did not report a
How We Teach

ROLE OF A TABLET DEVICE ON SCIENCE STUDENTS’ STUDY BEHAVIOR

Table 3. iPad participants’ reported time spent undertaking reading, writing, and interactive activities during private study

<table>
<thead>
<tr>
<th>Activity</th>
<th>Control Period</th>
<th>Trial Period</th>
<th>Significance (P Value)</th>
<th>Statistical Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reading activities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Online journal</td>
<td>24.5 ± 29.5</td>
<td>26.3 ± 27.9</td>
<td>&gt;0.05</td>
<td>Paired t-test</td>
</tr>
<tr>
<td>Hard copy journal</td>
<td>7.2 ± 12.5</td>
<td>17.3 ± 20.5</td>
<td>&lt;0.05</td>
<td>Wilcoxon signed-ranks test</td>
</tr>
<tr>
<td>Printed learning resources</td>
<td>14.9 ± 19.4</td>
<td>9.2 ± 19.2</td>
<td>&lt;0.05</td>
<td>Wilcoxon signed-ranks test</td>
</tr>
<tr>
<td>Hard copy book</td>
<td>21.9 ± 26.8</td>
<td>15.0 ± 24.8</td>
<td>&gt;0.05</td>
<td>Paired t-test</td>
</tr>
<tr>
<td>Reading Wiki(s)</td>
<td>4.6 ± 5.6</td>
<td>5.9 ± 7.1</td>
<td>&gt;0.05</td>
<td>Paired t-test</td>
</tr>
<tr>
<td>Website</td>
<td>5.6 ± 10.1</td>
<td>4.1 ± 5.8</td>
<td>&gt;0.05</td>
<td>Paired t-test</td>
</tr>
<tr>
<td><strong>Writing activities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pen and pencil</td>
<td>79 ± 45.1</td>
<td>47.5 ± 34.3</td>
<td>&lt;0.05</td>
<td>Paired t-test</td>
</tr>
<tr>
<td>Word processing</td>
<td>34 ± 33.8</td>
<td>67.3 ± 56.5</td>
<td>&lt;0.05</td>
<td>Paired t-test</td>
</tr>
<tr>
<td>Calendar</td>
<td>2.5 ± 3.8</td>
<td>3.8 ± 4.7</td>
<td>&gt;0.05</td>
<td>Wilcoxon signed-ranks test</td>
</tr>
<tr>
<td>E-mail</td>
<td>1.0 ± 3.4</td>
<td>6.0 ± 8.3</td>
<td>&gt;0.05</td>
<td>Wilcoxon signed-ranks test</td>
</tr>
<tr>
<td><strong>Interactive activities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast</td>
<td>6.5 ± 12.5</td>
<td>16.6 ± 28.1</td>
<td>&lt;0.05</td>
<td>Wilcoxon signed-ranks test</td>
</tr>
<tr>
<td>Search engine</td>
<td>12.7 ± 15.2</td>
<td>7.0 ± 9.5</td>
<td>&gt;0.05</td>
<td>Paired t-test</td>
</tr>
<tr>
<td>Audio recording</td>
<td>2.5 ± 8.3</td>
<td>13.0 ± 21.3</td>
<td>&lt;0.05</td>
<td>Wilcoxon signed-ranks test</td>
</tr>
<tr>
<td>Watching video</td>
<td>9.4 ± 22.3</td>
<td>7.7 ± 21.0</td>
<td>&gt;0.05</td>
<td>Wilcoxon signed-ranks test</td>
</tr>
<tr>
<td>Practice quizzes</td>
<td>3.5 ± 4.1</td>
<td>6.3 ± 14.6</td>
<td>&gt;0.05</td>
<td>Wilcoxon signed-ranks test</td>
</tr>
</tbody>
</table>

Data shown are means ± SD; n = 22 participants. P < 0.05 indicates a significant difference between control and trial periods.

significant use of discussion boards or blogs during the control or trial periods.

iPad participants reported some interesting changes in writing activities during the study (Table 3). iPad participants significantly increased the time spent word processing during the trial period. In the control period, participants recorded an average of 34 ± 33.8 min word processing, which increased significantly to 67.3 ± 56.5 min in the trial period, a 97.7% increase (P < 0.05, paired t-test, n = 22 participants). In conjunction with an increase in word processing for iPad participants in the trial period, there was a corresponding decrease in the use of pen and paper. Participants reported a significant (40%) reduction in the use of pen and paper between control and trial periods (79 ± 45.1 to 47.5 ± 34.3 min, P < 0.05, paired t-test, n = 22 participants). iPad participants also reported increased use of calendar and e-mail (Table 3). In particular, participants reported a significant increase in the use of e-mail from 1.0 ± 3.4 to 6.0 ± 8.3 min between the control and trial periods (P < 0.05, Wilcoxon signed-ranks test, n = 22 participants).

Use of podcasts by iPad participants significantly increased during the trial period. In the control period, the average time spent listening to podcasts was 6.5 ± 12.7 min (n = 22 participants). In the trial period, these participants listened to podcasts for an average of 16.6 ± 28.1 min (P < 0.05, Wilcoxon signed-ranks test, n = 22 participants). iPad participants also reported a significant increase in the use of audio recording tools in private study (2.5 ± 8.3 to 13 ± 21.3 min, P < 0.05, Wilcoxon signed-ranks test, n = 22 participants). iPad participants reported a reduction in the time spent using online search engines during the trial period, but this change was not significant (Table 3).

Participants’ opinions about the iPad. At the end of the trial period, iPad participants were asked a series of Likert-style questions about their experiences in using the iPad in their studies. Reliability analysis was conducted on the questionnaire responses, and Cronbach’s α was 0.76. Eighty percent of iPad participants reported that the iPad was a useful tool for studying, and 67% believed that the iPad enhanced their ability to study effectively. Ninety-six percent of iPad participants found the device easy to use, and only 43% believed that they would have benefited from additional training to use the device. Thirty-eight percent of iPad participants said they would recommend the device to a friend who was about to commence their undergraduate degree, and a further 38% were neutral about this statement. Fifty-nine percent of iPad participants agreed that the software applications provided on the device were useful aids for studying. However, 46% of participants believed that it required longer than 3 mo to be fully comfortable with the tools on the device. A large majority of iPad participants (96%) noted that they would have purchased apps or content for the device if they were keeping the device or being reimbursed for additional purchases.

Two focus groups were held with iPad participants during the trial period: the first around 2 wk after the devices were issued and the second 7–8 wk into the trial period. Over 80% of iPad participants attended the focus group meetings. During the first focus group discussion, participants discussed training, initial use of the device, concerns and issues, and general impressions. When questioned about the training, participants felt that having an initial session to learn how to use the basic tools, followed by more focused “app-centered” sessions later in the trial, would have been optimal. Participants were positive about learning how to use the device and were exploring more apps as time progressed. Participants’ main substantive concerns were about 1) the lack of continual and seamless access to wifi between accommodation, campus, and study areas; 2) risk of the device being lost, stolen, or broken; 3) bringing the device into laboratory classes; and 4) purchasing new apps for the device without compensation. Only two students reported taking out a 3-G data plan during the trial period.

During the second focus group, participants were asked to reflect on their experience of using an iPad while studying, focusing on practicality, use with other devices, and tool usage. Participants commented that they mainly used the device for reading and interactive activities, in preference to writing activities, due to issues with typing on the keyboard for long periods. When discussing the use of the iPad with other devices, participants reported using it in conjunction with other...
devices (mainly laptops). Participants reported that the iPad did not replace laptops for activities such as writing assignments, but it was preferable for taking to teaching classes for note taking, reading, and searching. Participants also reported that the iPad increased studying opportunities, due to its ease of use. Participants cited examples of spontaneous group working, studying while commuting, and studying during a short interval between classes. However, some students (mainly levels 2/3) commented that the iPad had not influenced their study habits, due to their existing (presumably successful) strategies and concerns about potential detrimental effects on grades. When discussing tool usage, participants expressed particular praise for Soundnote, PubMed on Tap, and GoodReader as useful studying tools. Participants expressed a desire to use eBook functionality in future, particularly for digital dissemination of course materials. Participants also expressed a desire for iTunesU material to be better integrated into course syllabuses. When participants were asked about whether universities should provide all students with a mobile device, such as an iPad, there were mixed views. Some participants were concerned about the cost implications, preferring money to be spent on laboratory facilities. Some participants expressed the view that mobile devices should be available for students to loan from the university. The majority of participants agreed that such a device should be preloaded with appropriate educational applications but that students should be able to also update the applications and configure the device themselves. Around 50% of participants believed that the offer of a mobile device would influence their decision as to whether to apply to a university for higher education.

**DISCUSSION**

The findings of the study will be discussed according to the two research hypotheses posed in the Introduction, followed by a discussion about participants’ perceptions about the tablet device.

**Impact of a mobile device on students’ device usage and study behavior.** The findings of this study indicate that this population of science students show broadly similar patterns of technology use and device ownership to other student populations recently surveyed, particularly in respect to mobile telephone/smartphones, laptops (or netbooks), and portable media players (8, 12, 24). Data from a variety of sources were used to show alterations in device usage: participants’ overall judgement about the frequency of device usage at the beginning and end of the study, participants’ responses to regular study habits questionnaires, and participants’ qualitative views in focus groups. This study showed that students adapted their device usage profile as a result of a tablet device, using it in preference to laptops, PCs, and smartphones for particular learning activities. Participants reported that the tablet device was more convenient as a study accompaniment, particularly when on campus, and they indicated that the device was easy to use with little training. These findings are supported by those of previous studies (18, 27) that have integrated mobile devices into classroom settings to complement face-to-face teaching with positive results. In this study, overall usage of the tablet device was very high, at >3 h per day, as indicated by total app usage time, indicating a group of students who are committed to studying and finding a variety of ways to use the tablet device to enhance their learning. Participant engagement with the study was high, with maintained use of the device throughout the trial period. Overall, these data illustrate a group of students making extensive use of a mobile device for learning activities.

Of course, these data should be treated with caution as the control and trial periods were conducted in different semesters of the same academic year and factors such as student motivation may have influenced their study behaviors in addition to the availability of a mobile device. However, participants’ overall time in taught classes was not different between control and trial periods, and they reported similar overall private study time. Participants did report spending longer studying in the library in the trial period, but this may be related to the profile of modules taken by participants in the trial period and may not be a result of the tablet device. Alternatively, it may be that participants shifted their study to the library as a result of poor wireless access in their private accommodation; this was not ascertained during the study.

Interestingly, participants reported increased time word processing during the trial period and a reduction in the use of pen and paper. These findings may indicate a move toward more time producing electronic notes or assignments on the device, which could have implications in the future for designing more assignments to be completed online. It is important to note that students did not purchase, or have access to, a wireless keyboard for the tablet device during this study. Word-processing time may have been higher had students used a wireless keyboard. Moreover, participants reported significantly reduced time using printed learning resources in the trial period, presumably as a result of viewing resources on the tablet device instead. A previous study (13) investigating the potential uses for tablet devices described similar observations. These findings may be particularly interesting to higher education institutions considering the cost-benefit analysis of mobile devices, given the potential savings in printing costs if students are able to access learning resources (e.g., lecture slides, practical resources, handouts, eBooks, etc.) on a mobile device. There was also a significant increase in participants’ use of e-mail during the trial period. This is likely to be due to the ease of access to e-mail via the mobile device, as opposed to students’ normal route of access through the institutional portal. Surprisingly, there was an increased use of hard copies of journals during the trial period, but no increase in online journal use. It may have been expected that there would be an increase in use of online journals and a reduction in hard copies of journals as a result of the mobile device. While it is not possible to fully explain these findings, it could be due to lack of electronic access to journals required by students participating in the study during the trial period, which would have produced the data observed. This is a subject worthy of future investigation.

Participants reported using particular tools on the device extensively: the most popular (and well used) was Soundnote, which was used extensively for recording audio in taught classes and taking synchronized written notes. This tool clearly met a significant desire by students for audio recording of lectures to use in their study and revision, despite the fact that in some modules lectures are recorded and made available for students. Discussions in focus group meetings revealed extensive sharing of Soundnote recordings between students, using file-sharing tools (such as Dropbox) and social networking.
sites, illustrating students’ ability to make use of collaborative Web 2.0 tools when desired. Previous studies (5, 15–17) have indicated the popularity (and usefulness) of audio recordings (and/or podcasts) of lectures published by teachers.

While there were some differences in app usage between students at different levels, the number of participants was small, and, therefore, the data should be treated with some caution. However, these findings suggest differences in students’ uses of mobile devices at different stages of their undergraduate degree. Students at level 1 concentrated on apps for writing notes and searching for background information, while students at higher levels made greater use of research tools. Furthermore, level 1 students were more amenable to allowing the tablet device to help them shape their study habits, while final-year students had more fixed views about how their learning was most productively conducted. These observations are worthy of more detailed research as they may help to inform institution’s policy and practices when implementing changes to curricula, teaching methods, and use of technology.

**Impact of a mobile device on students’ use of Web 2.0 technologies.** At the beginning of the study, participants reported extensive use of online search engines, but many other potential learning tools (e.g., wikis, podcasts, blogs, and discussion forums) were used infrequently by the majority of students. These findings echo detailed studies (8–12, 24) reporting Web 2.0 tool usage among undergraduate students. The tablet device did impact on the use of some Web 2.0 tools, as hypothesized, but had relatively little effect on students’ use of the majority of tools. Participants reported increased use of podcasts in both the overall questionnaire and through the study habits questionnaire, suggesting a real increase in engagement with podcasts for academic purposes. These findings are supported by previous studies (5, 15–17) investigating students’ engagement with podcasts for learning. While participants’ overall perception of their use of wikis was that it had increased by the end of the trial period, usage times of wikis were only slightly increased. This may be as a result of how data were collected in the numeric questionnaire: participants were asked to self-report usage of 15 min, 30 min, etc. It is likely that wikis were used for short periods of time (for example, to look things up in lectures), which may have been easily forgotten and thus not reported. This may not have been such an issue for other activities such as listening to podcasts, which were likely to have been longer study events. This issue of self-reporting may have also influenced participants’ reported use of online search engines in the numeric study habits questionnaire, which was shown to have reduced in the trial period. Participants’ overall impression of their frequency of use of online search engine usage was very high and unchanged between control and trial periods, and they reported high usage of the app Safari when reporting app usage times.

**Students’ perceptions about using a tablet device for learning.** An important aspect of the study design was to seek participants’ opinions about the usability and usefulness of the tablet device for learning, and views were garnered from individual interviews with participants, focus group meetings, and comments recorded on the study habits questionnaire and end-of-study questionnaire. Overall, participants found the device easy to use and convenient to carry to teaching classes. Participants received minimal training with the device, but the vast majority did not seek any additional advice about how to use individual applications, suggesting it provided an intuitive solution to most students. A variety of results indicate that the participants used the tablet device for a variety of activities, including reading, writing, and interactivity. Participants indicated that they had high levels of confidence and competence with use of the internet, software tools, and information literacy, and so they approached the device with a positive attitude towards computers and information technology, which is an important aspect of learner satisfaction with e-learning (1, 25). Participants requested better integration of Web 2.0 technologies into the curricula, citing increased use of eBooks and iTunesU material as particular examples that they wanted to see better exploited. These findings suggest that students will make better use of Web 2.0 technologies when encouraged to do so by their teachers, as can be achieved through blended learning scenarios (6, 15, 23). Students were also keen to explore further ways to make use of a tablet device in practical classes, for example, for watching equipment training videos, recording data, and collaborating with peers in group exercises. Perhaps surprisingly, the majority of students indicated that they would not recommend a tablet device to a friend entering higher education. While this finding was not corroborated formally within focus groups, comments from participants suggested it could have been due to the current relatively high cost of such devices.

**Conclusions and future research.** In conclusion, this small-scale exploratory study has revealed some interesting findings about the impact of a tablet device on biological sciences students’ use of technology and their study habits. The findings highlight a population of students at ease with technology but only using the most familiar tools for learning. Importantly, these findings are reported in a study where no attempt was made to alter curricula, teaching methods, or institutional systems for using technology. Therefore, participants’ use of the tablet device was entirely driven by individuals’ prior knowledge and motivation. Rigorous studies are now needed where a group of students on an individual science program or module are provided with a tablet device to investigate the impact on device usage and students’ perceptions when a teacher integrates Web 2.0 tools into their curriculum. Furthermore, studies are needed to overcome the limitations of this study, where data on tablet usage are collected in ways other than self-reporting. There are ongoing institutional trials embedding tablet devices into learning and teaching processes (for a reviews, see Ref. 7), for example, at Seton Hill University, where all students have been issued an Apple iPad (14). While there is a lack of empirical evidence in this area, early indications suggest that faculty members and students have benefited greatly from this innovation. Studies of this kind will provide empirical evidence of the impact of institutions modifying their teaching methods to encompass Web 2.0 tools and the effect this has on learners’ use of technology, both within individual modules and programs and in their everyday lives and academic studies. Importantly, higher education institutions should develop institutional strategies for the effective use of technology-enhanced learning and the integration of mobile devices (15). The 2011 Horizon Report (7) places “mobiles” in the “near-term horizon” category of innovations to watch carefully over the next 12 mo, alongside eBooks, primarily due to the ease of accessing information on the internet, highlighting the importance of mov-
ing forward with this area of technology-enhanced learning rapidly.

ACKNOWLEDGMENTS

The authors are grateful to all of the participants of the study.

GRANTS

This work was supported by the Faculty of Biological Sciences of the University of Leeds (Leeds, UK).

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

N.P.M. conception and design of research; N.P.M., L.R., and V.C. performed experiments; N.P.M., L.R., and V.C. analyzed data; N.P.M. and L.R. interpreted results of experiments; N.P.M., L.R., and V.C. prepared figures; N.P.M. drafted manuscript; N.P.M. edited and revised manuscript; N.P.M., L.R., and V.C. approved final version of manuscript.

REFERENCES


