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Mobile technology: students perceived benefits of apps for learning neuroanatomy

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Abstract Technology-enhanced learning is expanding rapidly because of research showing the benefits for learners in terms of engagement, convenience, attainment and enjoyment. Mobile learning approaches are also gaining in popularity, particularly during practical classes and clinical settings. However, there are few systematic studies evaluating the impact of tablet devices on students' learning in practical settings. The main aim of this three-year study was to gather rigorous evidence about students' use of apps on a preconfigured tablet device in a neuroanatomy practical class, their perceptions of this and the impact of the intervention on learning outcomes, using data collected from three cohorts of students between 2011 and 2013. Results showed that students made extensive use of resources provided, considered the devices to be beneficial for learning, and found them to be easy to use with minimal support and training. Students' ownership of touch screen devices increased significantly during the trial period as did their use of devices for academic study. Analysis of examination scores showed a statistically significant increase in performance for neuroanatomy-related questions after the introduction of tablet devices.

Keywords mobile learning, neuroanatomy education, practical exercises, tablet device.

Introduction

Blended learning, the use of technology and Web-based resources to augment face-to-face teaching (Sharpe, Benfield, Roberts, & Francis 2006), has increased steadily within the higher education sector over the last decade. Effective and well-designed blended learning approaches enhance student engagement, enjoyment and academic achievement (Beetham & Sharpe, 2013). There is an increasing expectation from millennial students that their higher education experience will include use of Web-based and interactive resources (Sharpe et al., 2006), and will integrate their personal computing devices into the learning experience (Dahlstrom, Walker, & Dziuban 2013). Many undergraduate students own or purchase a smart phone, tablet device or other mobile learning device to use at university.

Mobile learning, a branch of e-learning which utilizes the ubiquity and flexibility of mobile devices to offer students additional learning opportunities (Pachler, Bachmair, & Cook 2010; Vinu, Sherimon, & Krishnan 2011), is increasingly being used within the higher education sector, within a blended learning context (for a review, refer to, Naismith, Sharples, Vavoula, & Lonsdale 2004). Whilst the pedagogy of mobile learning is still emerging, there is a strong research focus on determining the impact of mobile learning approaches on student learning (Traxler, 2009; Kearney, Schuck, Burden, & Aubusson 2012). Whilst mobile learning approaches are commonly used with students working off-campus, for example, conducting fieldwork (Welsh, Mauchline, Park, Whalley, & France 2013) or in clinical settings (Lapinsky, 2007; Luanrattana, Win, Fulcher, & Iverson 2010; Clay, 2011), not all studies have found a

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positive effect of blended learning; for example, a previous study has found that taking notes on a laptop was less effective than longhand notes (Mueller & Oppenheimer, 2014). However, there is increasing evidence of their effectiveness to support and augment learning in more commonplace learning environments, for example, laboratory practical classes (Hwang & Chang, 2011). Mobile learning approaches have been shown to support a number of theories of learning, including behaviourist, constructivist, situated, collaborative and informal (Naismith et al., 2004), and pedagogical frameworks of mobile learning have summarized these activities within distinctive features, for example, personalization, authenticity and collaboration (Kearney et al., 2012).

The academic applications of mobile computing devices are very varied, and include information retrieval, communication, interaction, assessment, social learning, data input and professional development (Conole, De Laat, Dillon, & Darby 2008). The major potential of tablet devices is through the continual release of new software applications (apps) for use on the device. Apps available for learning anatomy include eBooks, quizzes, information, image banks, laboratory tools, note-taking tools and learning games (Lewis, Burnett, Tunstall, & Abrahams 2014). The potential for teachers to make good use of tablet computers in a practical class is very large, by utilizing the options for multimedia content, interactivity and portability, for example, practical instructions can be presented to students much more clearly, incorporating videos, interactive resources, record keeping and competency testing all on one device.

Anatomy education has become increasingly blended in nature in the last few years, often in response to student demand as a result of increased availability of handheld technologies and self-adoption (Trelease, 2008). Whilst use of lecture-based teaching, anatomy textbooks and hands-on experience in dissecting rooms are still the predominant form of instruction (Winkelmann, 2007), universities are also using prosections, plastinated specimens, models and simulations to support learning (Heylings, 2002). In addition, some UK universities have deployed mobile devices to medical students to increase learning opportunities (Apple Inc., 2013). A number of mobile learning approaches for anatomical education have been described in the literature. Mayfield, Ohara, and O'Sullivan (2013) evaluated an iPad-based dissection manual, and showed that it aided learner engagement, improved attainment and improved the efficiency and effectiveness of the class. Lewis et al. (2014) reviewed the features of a wide range of anatomy apps available for mobile devices, advocating the use of these apps to complement traditional teaching methods. However, there are no known studies evidencing the impact of using neuroanatomy apps on a mobile device on students' perception of learning in practical settings, and learning outcomes, with a number of student cohorts, which is the focus of this research.

This three-year study was designed to investigate the impact of introducing a preconfigured tablet device to a well-established neuroanatomy practical class on students' perception of learning and on their learning outcomes in the form of responses to multiple choice questions for three cohorts of students. The course chosen for this study (entitled 'Neurobiology') was taught by didactic lectures (approximately 20), four interactive online tutorials, a neuroanatomy practical class and a session in the dissection room (with prosected human brain tissue). Before this intervention, the neuroanatomy class consisted of students rotating around various stations and utilizing textbooks (e.g., Haines, 2004; Crossman & Neary, 2010) plastic brain and spinal cord models, microscopes and printed materials. The module was assessed by a number of in-course and end-of-course assessments: the in-course assessment consisted of an unseen essay examination and an anatomy spot test (conducted in the dissection room); the end-of-course examination consisted of a multiple choice question examination and unseen examination essays.

The pedagogical approach underpinning the use of mobile devices preloaded with neuroanatomy apps and study resources was devised to encourage student autonomy, problem-solving, improved 3D understanding of brain structures and independent learning, as demonstrated in earlier studies when mobile devices were introduced into classes to complement existing teaching practices (Lewis et al., 2014). Because of ethical concerns about inequity in the student experience, it was not possible to group students into trial and control groups; therefore, this study does not have a control group. The study, which collected data over a three-year period, compares the variation in quantitative responses between equivalent open cohorts, using statistical testing; this is a form of action research generally used to evaluate changes in practice and to advocate for change (Gall, Gall, & Borg 2007), taking into account the extant literature, the practitioner's experiences and input from others (in this case, students). Whilst much action research is participatory or observational, this research design aimed to offer rigorous quantitative data for analysis, in the form of a survey instrument and analysis of performance in examinations over a number of years.

The research study aimed to answer the following questions: (1) Have undergraduate biomedical science students' mobile device ownership patterns changed over a three-year period? (2) What are undergraduate biomedical science students' perceptions of the value of mobile learning? (3) Do three cohorts of undergraduate students studying a practical class use a tablet device in similar ways? (4) Does the availability of a tablet device configured with learning apps improve students' learning of neuroanatomy?

Method

Study design

The trial took place over three academic sessions (2011–2012, 2012–2013 and 2013–2014) and involved a level two undergraduate course (BMSC2118: Neurobiology). The teaching on the courses involved lectures and two practical classes. The trial involved one of the practical classes – a neuroanatomy class. Students enrolled on the course were emailed in advance of the class to inform them that the neuroanatomy practical session would include the optional use of preconfigured Apple iPad (First generation iPad, 16Gb, WiFi and 3G, Apple Inc., Copertino, CA, USA) devices to augment the learning experience, in addition to the normal learning resources. The students were informed that they would be asked to complete an optional questionnaire about their use of the tablet device at the end of the practical class. The practical class followed the same format each year, and the questionnaire was identical during all 3 years of the trial. The teaching staff members were the same in year 1 and year 2 of the study, but one member of the staff was not present in the practical class in year 3; the teaching staff interacted with the students in the class in the same way in each year of the study.

Configuration of tablet devices

Twenty-five Apple iPads were preconfigured with five apps installed from the Apple app store. Tablet devices were chosen for this study because of their portability, ease of use, touch screen functionality and the availability of apps suitable for use in the practical class. The devices were configured and maintained during the trials by an undergraduate student intern employed by the researcher. The student intern was not associated with the module in any way. Each iPad was configured identically and included the following apps on the home screen: 3D Brain (Cold Spring Harbor Laboratory, 2013), which allowed a 3D manipulation of brain structures as a whole or displayed individually using touch screen functionality. The app allowed structures (e.g., basal ganglia) to be displayed with (or without) labels and descriptions, and offered links to research articles for further reading; HD Brain (2010), which allowed static viewing of images of brain structures with accompanying descriptions; Sylvius MR: Atlas of the human brain (Sylvius, 2011), which involved MRI scans (in multiple planes) of brain structures and pin labels, including functionality to take quizzes to test knowledge of key structures; Google app (Google Inc., Menlo Park, CA, USA) for searching the Internet using the Google search engine, and Soundnote (2013) for typing notes with synchronized audio recordings. The apps chosen were specifically selected as the content and functionality provided closely aligned with the learning outcomes of the practical class, thereby offering a blended learning approach to the practical class, in which face-to-face instruction could be supplemented by the use of digital resources and tools. The iPads were configured with a background image providing basic instructions about how to use the tablet device and the functionality of each app. The students were also provided with instructions about how to access the Internet (via the University of Leeds WiFi system), and in-app guidance about how to send Soundnote notes to their email account. The students were offered support, if required, with use of the tablet devices during the practical class by the student intern supporting the trial. All data was removed from the devices between each practical session.

Distribution of devices in practical class

During the practical sessions, pairs of students rotated around 10 stations to help them to understand different aspects of neuroanatomy (e.g., histology, gross structures, ventricles, etc.), with assistance from academic staff and postgraduate demonstrators. The students were provided with a variety of learning resources during the practical class, including plastic brain models, printed information sheets and microscopes. The practical class was conducted in a clean classroom setting, so the students were able to handle all the equipments without the use of personal safety equipment. At the commencement of the practical, each pair of students was issued with a preconfigured Apple iPad along with an individual copy of the printed workbook, and was encouraged to use the apps on the device to supplement their learning. The tablet devices were only available within the specified practical class. However, in 1 year of the study, the students requested access to the devices outside of class time for use as a revision tool for the practical examination. This request was granted. As the apps were all available for installation on the students' own mobile devices, they were able to make use of the apps outside of the practical class, if they had the appropriate devices. The data on the use of the apps outside of the practical class is not available.

Data collection

A questionnaire was developed by the research team to collect demographic data, and the data relating to ownership and use of mobile devices and use and perceptions of the iPads and software used in the trial. The questions were of multiple-choice type, and used the Likert scale (strongly agree–strongly disagree). The survey instrument was developed using questions from previously validated surveys ascertaining students' use of mobile devices and technology (Morris, Ramsay, & Chauhan 2012), and the survey instrument was piloted with a group of student volunteers ($n = 10$; results not included in data set). The internal consistency or reliability of the survey was measured using Cronbach's Alpha (George & Mallory, 2008, p. 243). Cronbach's alpha was calculated as follows for each of the question sets, in line with common practice (Tavakol & Dennick, 2011): ownership and use of mobile devices, 0.51 (four items); perceptions of using iPads, 0.76 (six items); and use of apps, 0.60 (ten items).

Where the respondents were asked to indicate the time spent using each app, they were asked to select one of five options (not used, 1–9 min, 10–19 min, 20–29 min or over 30 min); during analysis, the median value was selected to calculate responses. A link to the questionnaire was provided on the tablet devices, and the students were asked to complete the questionnaire at the end of the practical session. All questionnaire responses were received during the practical class. The students were informed that completing the questionnaire was entirely voluntary and that they could withdraw at any stage. No personal data was collected using the questionnaire, and all responses were completely anonymous. All questionnaire data was transferred to secure university servers immediately after data collection. Ethical approval was obtained from the University of Leeds Ethical Review Committee. All the students completed the survey individually.

The students' scores for neuroanatomy-related multiple choice questions (MCQs) in the end-of-course summative examination in each year of the trial and in the pretrial year were collected. These four questions covered the content areas of 'the brainstem', 'structures visible on the dorsal surface of the intact human brainstem', 'spinal motoneurones' and 'neurones of the ascending auditory pathway synapses'. As a control, the students' scores from an equal number of MCQs that contained information not taught within the neuroanatomy practical class were also collected for the three trial years and the pretrial year. These four questions covered the content areas of 'GABA aminotransferase', 'the synthesis of dopamine', a nociceptive peripheral stimulus' and 'Pick's disease'.

Data analysis

Data were collated, organized and analysed using Microsoft Excel (2010). All multiple choice responses were coded, and % agree was calculated from combining the 'strongly agree' and 'agree' responses. The mean (with standard deviation) and median values were calculated and reported for app usage times, as a result of respondents selecting times from categories. Statistical analysis was conducted using SPSS Version 22 (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.). As the survey data was nonparametric ordinal data from unrelated populations, the Kruskal–Wallis H test was used to determine the statistical differences between cohorts. *Post hoc* testing was determined by pairwise comparisons between cohorts, and the Dunn–Bonferroni test was used. Statistical significance was assumed where $p < 0.05$. The students' scores for neuroanatomy-related MCQs in the end-of-course summative examination in each year of the trial were analysed, along with responses from the MCQs that contained information not taught within the neuroanatomy practical class, and compared to scores in the year before the trial was conducted. The students' average scores in each year of the trial (and the year before the trial) were compared using an analysis of variance (ANOVA) test and the *post hoc* Tukey HSD test. Statistical significance was accepted where $p < 0.05$.

Participant demographics

Undergraduate biomedical science students attended the two-hour neuroanatomy practical class ($n = 177$ year 1; $n = 167$ year 2; $n = 175$ year 3), in four separate sessions in groups of approximately 45 students. The students completed the online questionnaire on the tablet devices at the end of the practical class ($n = 114$, year 1, response rate 64%; $n = 85$, year 2, response rate 51%; $n = 90$, year 3, response rate 51%). There was a slight predominance of responses from female students in all years of the trial (61%–63%). All the students were in their second year (level 2) of an undergraduate degree program, and the majority of the students in every year of the trial were 20–21 years old.

Results

Participants' prior use of touch screen devices

The participants' laptop ownership was high and was largely unaltered in each year of the trial period (93%–98%). The proportion of laptop owners who took their laptops regularly to campus was consistently less than 50% (Figure 1). In contrast, the proportion of the participants owning a touch screen device increased significantly during the trial period (58.8% to 85.6%; Kruskal–Wallis H test $X^2(2) = 26.4$, $p = 0.0001$). Touch screen owners' use of their devices for learning increased significantly during the trial period (32.5% to 62.2%; Kruskal–Wallis H test $X^2(2) = 19.4$, $p = 0.0001$). These changes occurred alongside a significant reduction in the number of participants with little or no experience using touch screen technology (25% to 1%; $X^2(2) = 28.6$, $p = 0.0001$).

Participants' use of iPads during practical class

Throughout the trial, the most extensively used 'app' during the practical class was 3D Brain. It was used by

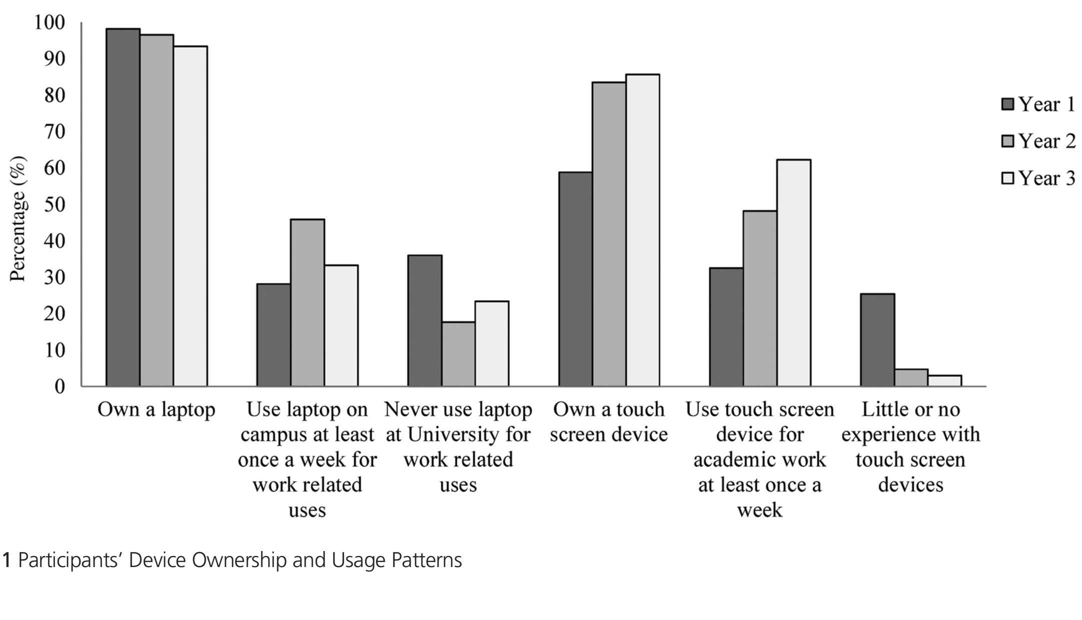

Figure 1 Participants' Device Ownership and Usage Patterns

between 81.1% and 98.2% of the respondents for median times of 5–15 min. 3D Brain also received the highest satisfaction rating from the participants: Between 65.6% and 98.2% of users agreed that it enhanced their learning in the practical class (Table 1). The other two neuroscience specific 'apps' (HD Brain and Sylvius) were used by fewer participants, for less time and with lower satisfaction ratings throughout the trial (Table 1). A large proportion of participants made use of the Google app in year 1 and year 2 (75.4% and 74.1% respectively), but this reduced to 44.1% in year 3 (Table 2). The Soundnote app was only used by a small number of participants throughout the trial (Table 1).

The respondents were asked how they had used the tablet device during the practical class, from a list of options (Figure 2). A large proportion indicated that they had used the device to 'look at images to understand brain structure' (81.1%–96.5%). A smaller but significant proportion 'looked up information or definitions' (51.8%–63.2%) and 'read text about the brain to understand structure/function' (51.1%–55.3%). Only a small proportion of respondents indicated that they had used the device for 'writing notes about things you have learnt' (5.9%–11.4%).

Participants' perceptions of iPads

Throughout the trial, the participants consistently indicated that use of iPads within the practical class had improved their learning (76.3%–82.4%) and had been enjoyable (77.6%–80.7%; Table 2). The participants also indicated that the device had been easy to use (78.9%–85.9%). The proportion of participants who indicated that more training was needed to make effective use of the device during the class significantly reduced during the trial (32.5% to 15.6%; Kruskal–Wallis H test $X^2(2) = 8.8$, $p = 0.012$; Table 2). The proportion of participants who were considering purchasing a tablet device was constant in year 1 and year 2 of the trial (57.0% and 57.6%), but dropped to 35.6% in year 3 of the trial (Table 2).

Table 1. % of Participants Using Each of the Available Apps During the Practical Class

	Year 1 ($n = 114$)	Year 2 ($n = 85$)	Year 3 ($n = 90$)
3D Brain (2013)			
% used	98.2	97.6	81.1
Median time (min)	15	15	5
Average time (±SD)	16.0 ± 9.7	15.7 ± 9.6	8.6 ± 8.4
% agreed useful	98.2	95.3	65.6
HD Brain (2010)			
% used	72.8	77.6	77.3
Median time (min)	5	5	5
Average time (±SD)	6.9 ± 7.7	9.2 ± 9.2	7.9 ± 8.2
% agreed useful	59.6	67.1	68.9
Sylvius (2011)			
% used	26.3	27.1	55.6
Median time (min)	0	0	5
Average time (±SD)	2.7 ± 6.1	2.5 ± 6.0	5.4 ± 7.3
% agreed useful	28.1	23.5	51.1
Google app			
% used	75.4	74.1	41.1
Median time (min)	5	5	0
Average time (±SD)	10.5 ± 10.1	7.3 ± 7.8	5.3 ± 9.0
% agreed useful	76.3	65.9	40.0
Soundnote (2013)			
% used	9.6	8.2	15.9
Median time (min)	0	0	0
Average time (±SD)	0.7 ± 2.4	1 ± 4.7	3.2 ± 8.4
% agreed useful	16.7	7.1	10.0

There were no statistical differences between these data for the 3 years of the trial.

Table 2. Participants' Perceptions of the iPads for Learning

	Year 1	Year 2	Year 3
iPads are positively beneficial to learning (i.e., understanding and knowledge) in class.	87.0 (76.3)	70.0 (82.4)	69.0 (76.7)
iPads made class a more enjoyable learning experience.	92.0 (80.7)	66.0 (77.6)	71.0 (78.9)
More training needed to use iPads	37.0 (32.5)[a]	17.0 (20.0)	14.0 (15.6)[a]
Ease of use	90.0 (78.9)	73.0 (85.9)	75.0 (83.3)
Considered tablet purchase after class	65.0 (57.0)	64.0 (57.6)	32.0 (35.6)

Note. The table illustrates the number and percentage of participants who agreed with each of the statements (% in parentheses) in each year of the trial. Significant differences between cohorts were tested using the Kruskal–Wallis H test.
[a]Indicates $X^2(2) = 24.4$, $p = 0.014$.

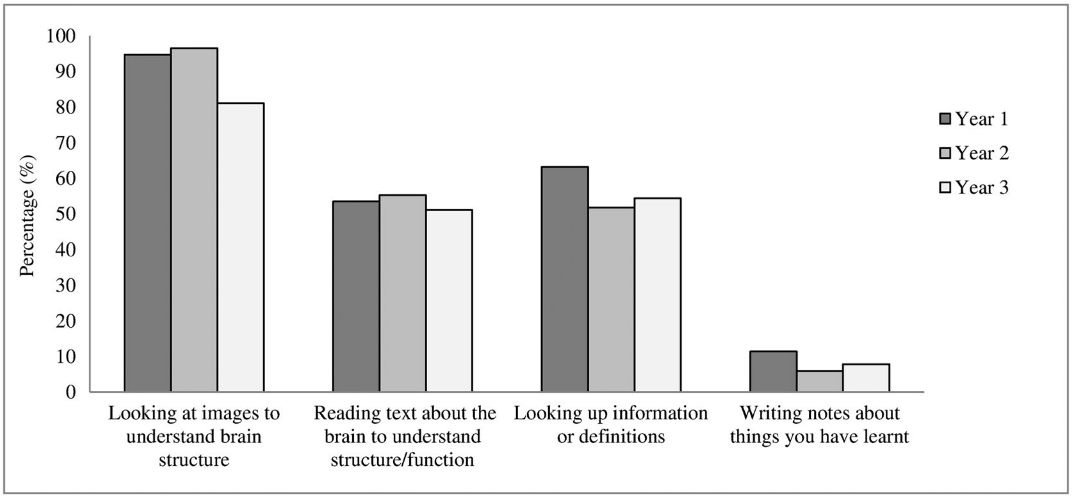

Figure 2 Use of the Tablet Devices for Learning

Examination performance

Four neuroanatomy-related MCQs were included in the final summative examination for the module in all years of the trial, and the year before the trial started (Table 3). The average score for the neuroanatomy-related MCQs increased significantly between the year before the trial and the 3 years of the trial ($p = 0.028$, $F = 4.306$, DF = 15; partial eta squared = 0.52; the data passed a homogeneity of variance test, Levene statistic, $p = 0.714$). *Post hoc* analysis revealed that the students' performance in neuroanatomy questions in year 1 and year 2 of the trial was significantly better than their performance in the year before the trial ($p = 0.04$, $p = 0.047$ respectively, Tukey HSD test). As a control, an identical test was performed on four randomly selected MCQs that contained information not taught in the neuroanatomy practical class included in the final summative examination for the module (Table 3). There was no significant difference in the students' average scores between the year before the trial and any of the years of the trial (Levene statistic $p = 0.375$; ANOVA, $p = 0.969$, $F = 0.082$, DF = 15), which suggests that the improvement in performance for the neuroanatomy questions was not a sample effect.

Discussion

The main findings of this study were that the students make significant use of preconfigured tablet devices within practical classes to support their learning, and do so without significant training or support. Also, undergraduate students' device ownership patterns have altered between 2011 and 2013, with more students

Table 3. Average Scores for Neuroanatomy and Non-Neuroanatomy-Related Questions on Final Exam

	Pretrial (n = 199)	Year 1 (n = 172)	Year 2 (n = 193)	Year 3 (n = 168)
Neuroanatomy-related questions				
'Regarding the brain stem'	39.2	74.4	72.0	67.3
'The following structures are visible on the dorsal surface of the intact human brain stem'	36.7	53.5	50.3	54.2
'Concerning spinal motoneurones'	48.2	66.3	70.5	64.3
'Neurones of the ascending auditory pathway synapses'	58.8	65.1	64.2	61.3
Average % score (±SD)	45.7 ± 10.0[a]	64.8 ± 8.6[b]	64.3 ± 9.9[c]	61.8 ± 5.6
Non-neuroanatomy-related questions				
'GABA aminotransferase'	22.1	31.4	32.1	44.6
'The synthesis of dopamine'	89.4	84.3	74.1	89.3
'A nociceptive peripheral stimulus'	68.3	70.3	75.1	71.4
'Pick's disease'	27.1	39.5	40.4	38.1
Average % score (±SD)	51.7 ± 32.5	56.4 ± 25.0	55.4 ± 22.4	60.9 ± 23.8

These average scores were calculated using the Speedwell Multiquest computer marking system which does not report standard deviation. The pretrial average % score for neuroanatomy-related questions was significantly lower than for the trial years. There was no significant difference in average % scores for the questions not taught in the neuroanatomy practical class.
[a]ANOVA $p < 0.05$. [b]*Post hoc* Tukey HSD test $p < 0.05$. [c]*Post hoc* Tukey HSD test $p < 0.05$.

owning touch screen devices and using them to support academic work. Furthermore, the students' performance in neuroanatomy-related questions improved in a summative examination. The results of this study provide evidence for anatomy and physiology educators that integrating mobile learning opportunities into the curriculum can enhance students' perception of their learning and enjoyment within classes, with minimal support and training.

Integration of tablet devices in practical settings

The results of this study illustrate that a preconfigured tablet device can be successfully integrated into an existing anatomy or physiology practical class, without major changes to the design of the class, the intended learning outcomes or the IT skills of the academic teachers. The students reported that the integration of tablet devices into a practical class was beneficial for learning, as seen in other iPad deployment trials in other disciplines (Rossing, Miller, Cecil, & Stamper 2012; Stringer & Tobin, 2012). Overall, the results of the study demonstrate that the tablet devices were used by the students for information retrieval and conceptual understanding; these were key learning objectives for the practical class which sought to increase the students' conceptual understanding of key brain structures and their functions, in preparation for later dissection room-based classes. The integration of a tablet device into the classroom, and availability of the 3D Brain, HD Brain and Sylvius apps, improved the students' perception of their ability to understand the relative position, landmarks and functions of a wide range of key components of the brain and spinal cord. The integration of tablet devices into this practical class was successful because it aligned closely with the intended learning outcomes of the class, the existing resources and the teaching practices in operation (Harris, Mishra, & Koehler 2009; George-Walker & Keeffe, 2010).

A key finding of the study was that the students mainly used the devices for information retrieval and research, as seen in other studies (Judd & Kennedy, 2010; Mang & Wardley, 2012). However, they did not use the devices for recording information in written or audio form, despite the availability of the Soundnote app, which has been very popular in previous trials using tablet devices (Morris et al., 2012). This is likely to be for a combination of reasons: firstly, the students were recording information on a worksheet which was provided to support students' learning in the practical class; secondly, because of the time constraints in the practical class, the students were unlikely to explore the functionality of Soundnote, which requires a little more understanding than the other apps available on the device. There was a reduction in the participants' use of the 3D Brain app and the Google app in the third year of the study, alongside a modest increase in the use of Sylvius and

Soundnote. Whilst there is no clear reason for this change, it may have been a result of the students' increased confidence with tablet devices encouraging more use of a range of apps.

Overall, these findings are in line with previous studies and conceptual frameworks of technology acceptance (e.g., unified theory of acceptance and use of technology), which demonstrate that a number of factors influence users' acceptance of technology, including perceived ease of use, perceived usefulness, behavioural intention, effort expectancy and social influences (Venkatesh, Morris, Davis, & Davis 2003).

Changes in students' device ownership and use

The replication of the trial with three student cohorts between 2011 and 2013 enabled the researchers to investigate changes in the students' device ownership and use of devices to support learning. Firstly, the study showed that the students' ownership of laptops was similar across the cohorts, as was their (low) use of laptops on the university campus (Kay & Lauricella, 2011). In contrast, there were significant increases in the students' ownership of touch screen devices (e.g., iPhone, iPad and other mobile devices) between the three cohorts and in their usage of these devices for academic study. In support of this, there was a significant reduction in the number of students who considered themselves to have 'no or little' experience of touch screen devices between the three cohorts. These findings are supported by other studies of undergraduate student device ownership (Dahlstrom et al., 2013), and are indicative of a changing population of students who increasingly expect to use their mobile devices as part of their academic study (Conole et al., 2008).

Effect of blended learning approach on examination performance

The results demonstrate that the students' understanding of neuroanatomy improved as a result of the introduction of a blended learning approach to the practical class. Other studies have demonstrated improved learning outcomes as a result of similar blended learning interventions (Taradi, Taradi, Radić, & Pokrajac 2005; Green, Farchione, Hughes, & Chan 2014). Whilst the results described here are unambiguous statistically, there are some limitations which should be borne in mind when interpreting the improvements in examination performance, as is commonly the case in studies of this kind. As it is practically very difficult and educationally undesirable, to ensure that a course remains identical over a four-year period, there was a change in the format of the module assessment between the pretrial year and the trial years of the study, alongside the introduction of the tablet devices to the practical class: the assessment of the neuroanatomy aspect of the course was changed from a practical workbook to a spot test (with the same assessment weighting). This change may have contributed to the improved learning outcomes described in this study. However, alongside the students' positive perceptions of the impact of the tablet devices on their learning, the improvements in the students' examination performance are positive illustrations of the powerful impact of mobile devices in practical learning environments.

Provision of tablet devices in practical settings

In this study, the integration of tablet devices into the practical class was straightforward, as the class was conducted in a classroom setting; however, many practical classes are in laboratories, where the use of tablet devices may pose health and safety concerns. Indeed, the second practical class for the module in this study was in the university's dissection room, where no mobile devices are permitted. The integration of tablet devices into that scenario would have been more complex. This is a factor that must be considered carefully by educators planning on integrating tablet devices into practical settings (Mang & Wardley, 2012).

Providing students with devices versus 'bring your own device'

In this study, the students were provided with a preconfigured tablet device, to use in pairs. The technical support for the study was provided by a student intern, who prepared the devices, supported them within the classes and removed data from them between classes. The student intern was available to support students who needed help with the equipment, but this was not requested. Whilst this was not a large overhead with the number of tablet devices deployed, it is not an approach that could be supported with large numbers of devices. In that scenario, central IT services would have been required to configure and support the devices, which would have increased the costs of the intervention considerably. Also, as tablet devices are intended for personal use, the apps used had to be selected carefully; none of them required personal data (e.g., username and passwords) to be entered, and they did not create any personal profiles. The only challenge faced in this study was connecting to the institutional WiFi system which required personal credentials. These credentials were removed from the device between each student's use, illustrating the challenge of sharing devices intended for personal use.

Therefore, educators may consider replicating this study using students' own touch screen devices. Instructions could be provided to students to download the required apps in advance of the practical. The downside of this approach is that students own a wide variety of types of mobile devices, not all of which will be able to access the same apps. This can present inequity for students and challenges for educators to support different types of device within the class (Traxler, 2009, 2010). However, the 'bring your own device' approach is generally more efficient from a support and cost perspective for universities, and is gaining appeal across the sector (Karnad, 2013). The growing ownership of mobile devices by students is providing a wealth of opportunities for using technology in education, such as for revision purposes, which some of the students in this trial requested, or for assessment, personalization of learning by adapting the provision of content to student need, viewing captured lectures, a research tool to find information, for group working with the use of wikis, discussion forums, blogs, etc. There are many possible uses, including students' own innovative adaptations of the technology. Providing students with ways to use their devices, such as a list of 'useful' apps or suggested ways in which they can work together may encourage their increased use of their mobile devices for educational purposes.

Limitations

The authors are aware of certain limitations of this study. It was not possible to carry out a study involving an experimental and a control group as it was not deemed ethically acceptable by the research team and the University of Leeds ethical review committee, to only provide the use of iPads to 'some' students, as those not given this provision may be deemed to be at a disadvantage. It has also not been possible to include any additional pre-trial data, as the module did not exist in this form in earlier years. In year 3, one of the tutors was not available, which may have affected the trial results, although all other tutors were identical, and the teaching method was identical. We are aware that the question set 'ownership and use of mobile devices' has a low alpha value of 0.51, and thus the questions in this set are not necessarily measuring the same construct.

We also would have liked to have trialled the use of iPads in more than one practical class per year, but this was not possible as the module has only one class of this kind each year. However, to compensate, the research project collected data from three cohorts over three consecutive years. The research design was chosen to measure the impact on learning outcomes for multiple cohorts, to minimize the probability of results being obtained by chance as well as to measure change over time.

The students, in their comments, suggested that they would have liked more time to use the learning resources in the practical class, and one student suggested that additional training might have helped. However, previous studies conducted by the author have demonstrated that simply providing practice/tutorials on the use of apps does not necessarily increase their use by students (Morris et al., 2012). The Soundnote app, which requires a little more understanding than the other apps available on the device, was used less than other apps, but this is likely a result of it not being wholly appropriate to the task. Despite these limitations, the statistical analysis is robust and shows a large effect size.

Conclusion

This study has demonstrated that students value the integration of tablet devices into a practical class, indicating that they are beneficial to learning, increase enjoyment and are easy to use without training or support. Also, the data from three cohorts of students demonstrated which of the apps provided were used by the students and found to be useful in the learning scenario described. Examination performance in neuroanatomy-related MCQ improved as a result of the introduction of blended learning approaches. Finally, the study demonstrated significant changes in students' device ownership between cohorts, illustrating the increased use of touch screen devices for academic study.

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Appendix: Survey Instrument

1. How old are you?

18–19
20–21
22–24
25 or over
Prefer not to say

2. Are you male or female?

Male/Female/Prefer not to say

3. What programme are you studying?

Medical Sciences
Human Physiology
Neuroscience
Pharmacology
Sports Science and Physiology/Sports and Exercise Science
Other

4. How often do you bring your laptop into university for work-related uses?

More than three times a week
One to three times a week
One to three times a month
Once or twice a semester
Never
I do not own a laptop

5. Have you had much experience with touch screen technology before?

I own an iPhone
I own another type of touch screen smart phone (e.g., Nokia, Samsung)
I own another type of tablet device (e.g., Android tablet, Blackberry playbook)
I do not own any touch screen-based devices but have used them often
I have very little experience with touch screen-based devices
I have no experience with touch screen-based devices

6. On a scale of 1 to 5 (where 1 is very easy and 5 is very hard), how easy did you find it to pick up and use the iPad?

7. How strongly do you agree with this statement: 'I found the use of iPads to be positively beneficial to my learning (i.e., understanding and knowledge) in this lab class'

Strongly agree
Agree
No opinion
Disagree
Strongly disagree

8. How strongly do you agree with this statement 'Using the iPads made the lab class a more enjoyable learning experience'

Strongly agree
Agree
No opinion
Disagree
Strongly disagree

9. How strongly do you agree with this statement: 'I believe that regular use of iPads in taught classes would have a positive effect on my education'

Strongly agree
Agree
No opinion
Disagree
Strongly disagree

10. How strongly do you agree with this statement: 'It would have helped me to receive more training on how to use the iPads before this lab class'

Strongly agree
Agree
No opinion
Disagree
Strongly disagree

11. After using the iPads in class, would you consider purchasing an iPad or other tablet device?

I already own one, or a comparable tablet device
I have considered purchasing one for academic use
I have considered purchasing one for academic and social uses
I have considered purchasing one for nonacademic use (i.e., for social use)
No. I do not have any plans to purchase a tablet device

12. If you own a touch screen device, how often do you use it for academic work or learning?

More than three times a week
One to three times a week
One to three times a month
Once or twice a semester
Never
I do not own a touch screen device

13. How long (in total) did you spend using each of the apps available on the iPad?

Didn't use, 1–9 min, 10–19 min, 20–29 min, Over 30 min
a. 3D Brain
b. HD Brain
c. Google
d. Sylvius (Modality)
e. Soundnote

14. How useful were each of the apps for enhancing your learning in the lab class?

Very useful, useful, not very useful, not at all useful, not used
a. 3D Brain
b. HD Brain
c. Google
d. Modality
e. Soundnote

15. How did you use the iPad during the lab class? (select all that apply)

Looking at images to understand brain structure
Reading text about the brain to understand structure/function
Looking up information or definitions
Writing notes about things you have learnt

16. If you have any comments about the use of the iPad in this lab class, please write them in the box below. (Optional)