A study of effective and best practice usage and implementation of tablet PCs in engineering education

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Abstract

There are certain limitations with traditional presentational-style ('PowerPoint') lectures that must be addressed in order to improve the quality of lecturing and meet students' expectations on lecture quality and experience. Tablet PC devices can offer a suitable compromise between the progressive style of delivery of traditional blackboard/overhead projectors, and the ability to deliver multimedia material in an integrated session. In this paper the effectiveness of a tablet PC in an engineering education setting was examined from the point of view of both lecturer/ instructor and student. This was done via a survey of existing work fousing on four key usage models : i) a device for lecture delivery, ii) a device for student study, iii) a channel for instructor -student communication and iv) a device for productivity. From this the key benefits and limitations were identified with regards to suitability, functionality, and implementation. A series of best practice approaches were then devised to best implement tablet PCs into engineering education courses. Tablet PCs are shown to be very effective in creating active learning environments (ALEs) which are are beneficial in catering to more learning styles, improving engagement, and, subsequently, cognition and attendance.

Keywords: Tablet PC; Engineering education; Active learning environment.

Introduction

The modern lecture

Lectures, in a traditional sense of the word, are a formal, one way transfer of knowledge by spoken or illustrated word. Due to constraints on time and the ubiquity and ease of creating presentational style Microsoft PowerPoint lectures, they have become the norm for a large number of university and instructional courses . Lectures serve to impart information to students and are the most direct and efficient means to do so. However, this alone is not sufficient for building understanding— that ideally comes from a student's own studies, complimentary tutorials, and seminars. Lectures are effective in *instruction* and *delivering knowledge ,* but are not sufficient for *learning.* A form of verification (i.e. reflection) is required via feedback, peer assessment, and/or demonstration of knowledge (Anthony, 1996). Unfortunately, over time, the lecture has taken on a more prominent role in student's expectation of the learning activity, but can only ever be one part of it.

Research by Sander et al (2000) highlighted that students would like to be taught through a combination of interactive lectures and group based activities. Formal lecturing appears to be the least favourite method of students. Indeed, the effectiveness of PowerPoint slides is greatly limited due to the inability to adjust content in reaction to students' responses (Goh et al, 2013). This lack of interaction stifles student engagement and thus cognition. It is perhaps unsurprising then that students mostly dislike lecturing, preferring instead smaller group seminars and tutorials (Kandiko & Mawer, 2013).

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Due to the significant change in the higher education market in the UK in 2012 there has been a business-driven need for universities to improve the perceived quality and consistency of its courses to students. Several concepts have been promoted in recent years to achieve this: the flipped classroom model in particular (see Lage et al, 2000, or Crouch & Mazer 2001, for example) has been proposed as a means to increase interactivity by transforming the lecture into a seminar like discussion of material that students are asked to view before hand. This creates more time for tutorial style interaction, but is still of limited use in large classes, and imposes a requirement that students view the material prior to the session. It also requires a fundamental restructuring of a lecture course. Instead, there are possible options to maintain a traditional class structure, but improve the pacing and interactivity of slide based, lecture sessions. IT resources are believed to play an important part in improving the student experience by leveraging technology to provide more effective sessions, as well as provide flexible study resources and create intuitive channels of communication to students (Gordon, 2014). An increasingly popular tool being explored to that end is the tablet PC.

Tablet PCs

Bill Gates is credited with the term 'Tablet PC' in 2001. The electronic ink (e-ink) capability is the crucial functionality that sets it apart from other portable computers. One arguable benefit of overhead projectors (and their modern equivalent: the document projector) that was lost in the transition to PowerPoint slides was the progressive manner of development of material in the lecture through written material. Such a feature is significant when delivering complex engineering concepts. The synchronisation of both visual and verbal information is likely superior for student cognition (Hegarty, 2004; Walker et al, 2008). With PowerPoint slides it is very difficult to recapture this behaviour, which in the moment may be critical to help students follow the development of information and maintain focus. There is also more chance for interaction and discussion with students when material can be added to a live document or sheet. Tablet PCs are well suited for this capability and would make it possible to provide both progressive delivery of information with computer based multimedia content. Benlloch-Duulde et al (2010) provide a very thorough conceptual map for the possible uses and advantageous features offered by Tablet PCs.

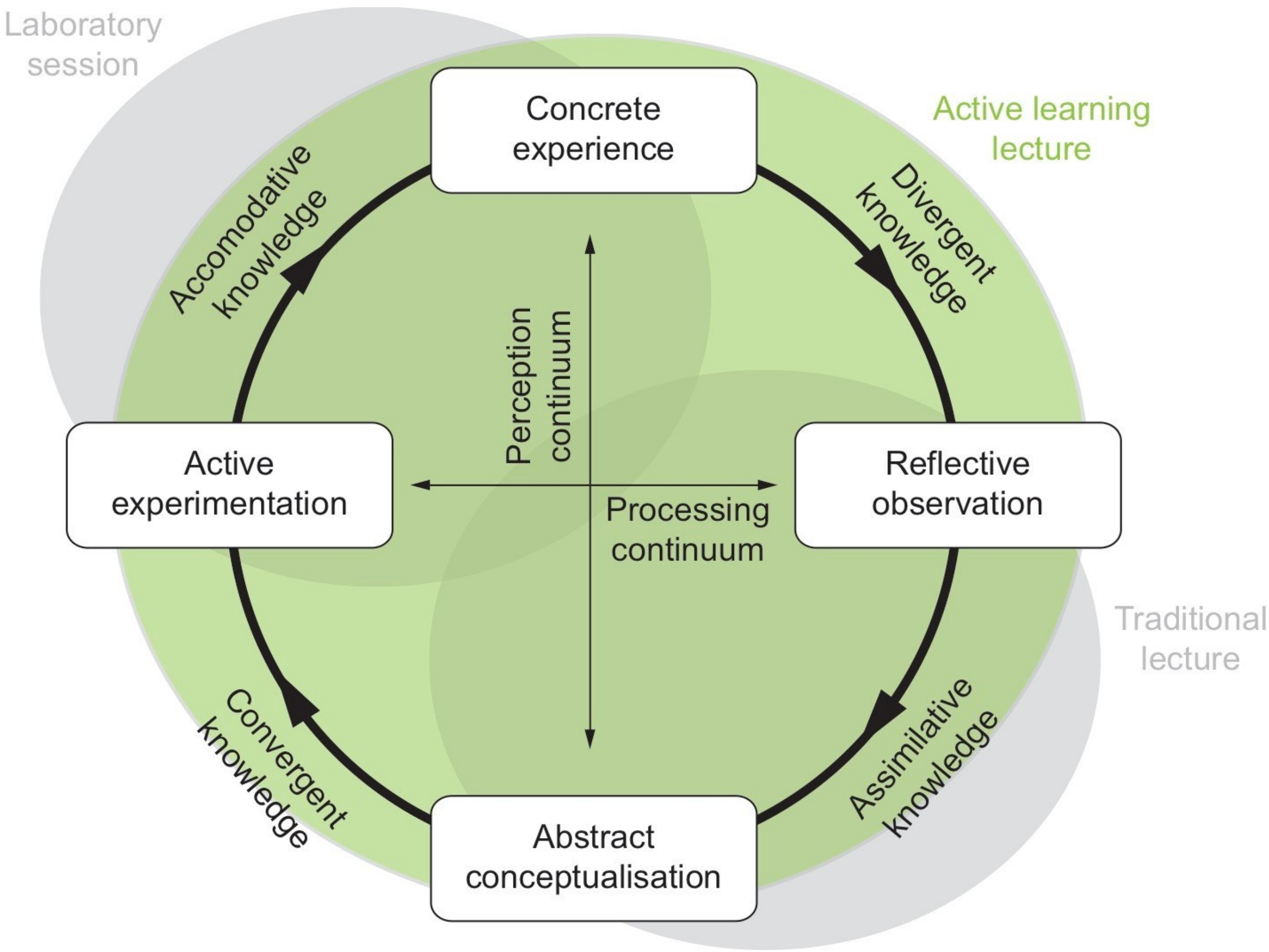
Much is made of the tablet PCs in providing a platform to produce an active learning environment (ALE). A rather loose definition of this is provided by Prince (2004):

"Active learning is generally defined as any instructional method that engages students in the learning process. In short, active learning requires students to do meaningful learning activities and think about what they are doing. … Active learning is often contrasted to the traditional lecture where students passively receive information from the instructor."

Learning is evidently a process, and modern thinking places greater importance on a multi-faceted approach (i.e. connectivism; see Lachman, 1997) rather than a specific method to create a desired product (the behaviourist model). In that sense the term 'active' learning is somewhat spurious since 'true' learning must always be active (see Adler, 1982).

The benefits of tablet PC use in creating ALEs are illustrated in Fig. 1, utilizing Kolb's experiential learning cycle (Kolb, 1976, 1984). A traditional lecture may only capture the bottom right quadrant of the cycle. with reference to Honey and Mumford's (1986) learning

Fig.1. The extent of traditional, laboratory, and active learning environments on capturing Kolb's experiential learning cycle in sessions.



Styles such as lectures would exclusively favour 'Reflectors' – those who prefer to watch and listen, gathering information before utilising it to solve problems. However, many commentators have observed the majority of engineering students to be visual, inductive, active learners (Felder & Silverman, 1988; Water-Perez et al, 2012). Tablet PC-based sessions have been demonstrated to facilitate a broader inclusivity of learning styles (Stickel, 2009; Kothaneth et al, 2012), and thus support the entirety of Kolb's learning process in one session.

The aim of this paper is to review the current literature on the use of tablet PCs in the education disciplines in a university context, and establish from them best practice uses to implementing them in a lecture session. As the devices are of use to both staff and students , the benefits to both will be reviewed and to what extent these benefits come at different scales of implementation

Best practice use of Tablet PCs

Methodology

The analysis of the literature has focused on four different uses for tablet PCs: i) a device for lecture delivery, ii) a device for student study, iii) a channel for instructor-student communication, and iv) a device for productivity. The majority of the literature falls within the first three of these categories. The literature surveyed has also been restricted mostly to that involved with engineering education as they deal with specific issues related to the discipline; namely the delivery of system diagrams, conceptual frameworks, and theoretical and mathematical derivations. Existing works were searched for primarily using Google, Google Scholar, SCOPUS, IEEE Xplore and using combination of the search terms “Engineering Education”, “Tablet PC”, and “Active learning” A more general review of tablet PC use can be read in other works (e.g. Mckenzie & Franke, 2009).

i) A tool for lecturers

The most widespread use of tablet PCs in a lecture/instructor environment is by modifying lecture slides with parts to complete in class via e-ink. Even this relatively trivial implementation is reported by students to have benefited their attention and engagement (e.g. Walker et al, 2008)

In a recent tablet PC trial undertaken by Thomas (2014) the devices proved very capable in achieving the desired changes in pacing and interactivity of their lectures, which most students preferred over PowerPoint slide based lectures. A similar observation was made previously by Singhatanadgid & Sripakagorn (2012). Hieb & Ralston (2010) comment that due to the use of a tablet PC instructors increased eye contact with students and made significant savings in time and energy by not needing to erase material from a whiteboard. Generally, lecturers have been positive about the natural writing mechanism that tablet PCs support (Tront, 2006). The ability to sketch over existing figures and diagrams, or create new ones live, as well as make annotations and comments is very consistent with the development and instruction of engineering material.

ii) A tool for students

Virginia Tech is widely referred to as a pioneer of achieving an integrated, committed active learning environment with its mandatory policy of every first year student purchasing a tablet PC for their engineering college. The ground work for integrating tablet PCs into the college’s curriculum came with pilot studies in 2002 into exploiting the tablet’s e-ink features (Tront, 2007). By 2005 they were experimenting with two-way student-instructor communication (see next section) and student collaboration in classes (specifically, a trial of 20 shared tablets between 40 students). In 2006 they introduced their tablet PC policy for every student. Other universities, such as the University of Louisville, have also adopted the same policy.

For students a tablet can facilitate the ability to work interactively within the lectures, collaboratively with other students, and allowing note taking in a natural manner which has been shown to increases cognition (e.g. DiFesta and Gray, 1972; Colwell, 2004; Tront et al, 2007). This is explained in terms of greater cognitive processing that occurs when longhand note-taking students are required to summarise or paraphrase notes, whereas laptop users almost invariably transcribed lectures verbatim, even when encouraged not to (Mueller and Oppenheimer, 2014). Furthermore, the digitisation of their notes makes it easier to organise, search, and review. This is especially important in an engineering context as it can instil in students the important skills of recording design decisions, analysis history, and minutes from meetings and communications (Firth & Surgenor, 2006). Lohani et al (2008) used this aspect effectively to teach and encourage students to maintain a properly laid out electronic logbook. Kothaneth et al (2012) had students work cooperatively with tablet PCs in class, which helped them to share ideas and engage in peer instruction and review.

iii) A tool for student-instructor interaction

As tablet PCs are typically wireless enabled devices they can be used as part of an integrated wireless ALE for real-time student assessment and feedback. The key requirement for this kind of integrated session is a classroom management software (CMS). One such CMS is Anderson's popular 'Classroom Presenter' (Anderson, 2006). Classroom Presenter is particularly powerful in providing bi-directional communication and sharing between instructors and students, via a localised ad-hoc wireless network. Existing lectures in PowerPoint can be converted to a proprietary format to enable effective annotations to be added to slides. Whilst menial to do, it can provide opportunity to introduce more involved activities with students (Tront, 2005; Bonastre et al, 2006; Cao, 2014). Other software available includes 'DyKnow Vision' (see Fang, 2012) or 'NetSupport School' (Enriquez, 2005, 2007). This software was also used by Rawat et al (2008) who argue it can encompass all of Chickering & Gamson's (1987) seven principles of good practice into the classroom. At Virginia Tech the lecturers noted significantly higher levels of active participation in set exercises in their ALE (Tront, 2005). Students were reported to prefer these interactions to CRS (classroom response system) clickers due to to the increased communication, enabling the instructor to assess the process in the task development, not just the final results.

A significant feature of these CMS is that students can access the lecturer's slides (with recently added annotations) in class, and add their own annotations. The lecturer can also receive the students' annotations and display to the rest of the class. In the same way as CRS systems this can remove barriers to engagement. Additionally, the benefit of this kind of wireless bi-directional communication is very rapid detection of student comprehension, which can then inform immediate feedback (see also Koile & Singer, 2006). The feedback (both instructor and peer) can be more comprehensive than that possible from CRS. This is very beneficial as feedback is one of the main aspects students are frequently critical of (Dearing, 1997, p. 117; also still apparent in recent National Student Survey results to date) despite often being indifferent to it (Wotjas, 1998; Duncan, 2007). Students regularly have difficulty in critiquing their own works, and guided reflection in the context of the purpose and rationale for the work has noticeable improvements (Thorpe, 2002). ALEs would facilitate this behaviour well.

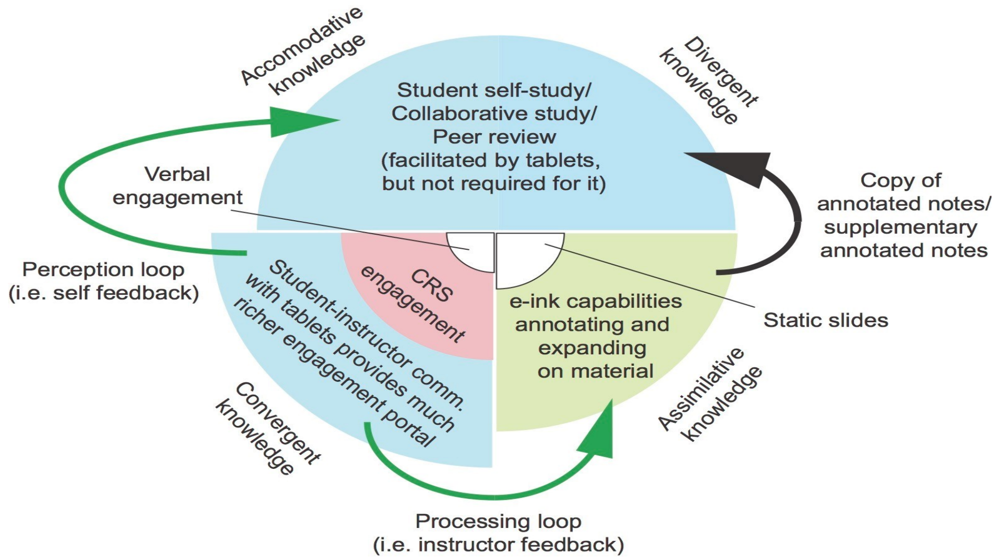
iv) A tool for productivity (staff and students)

It is also worth pointing out that tablet PCs can offer productivity improvements out-of-class, particularly in terms of workflow and assessment marking. Many lecturers have also expressed the improvements in efficiency and detail of feedback in marking assessments that the e-ink capability provides (e.g. Gorgievski et al, 2005). There are examples of tablet PCs being effective in laboratory classes (Rawat et al, 2008) and as electronic log books for students (Lohani et al, 2008). One example suggested by a lecturer was a wireless mobile user interface for a Labview-based lab session (Thomas, 2014). The portability of the devices also makes them very attractive for field work where time savings can be made (Benison et al, 2006). As capable multimedia devices they also provide a gateway to VLEs as well as external learning resources. Note that this is useful for both staff and students.

Implementing tablet PCs into lectures effectively

Following a review of the literature, the benefits of tablet PCs have been summarised in Fig. 2. In this diagram, which maps loosely to Kolb's learning cycle in Fig. 1, the greater distance from the centre illustrates greater expected student engagement. Whilst it may be possible to encourage accommodative and divergent knowledge in lecture, much of this would be expected to occur outside with student self-study where they have the chance to experiment and experience the knowledge obtained in the lecture. A tablet PC used by a lecturer may greatly improve the assimilative phase of the lecture, but real improvement elsewhere requires input from the students, where student-operated tablet PCs may help. It must always be remembered that using a tablet is not sufficient to create an ALE. The aims of this paper have been to show how tablet's can be used to assist and facilitating their implementation.

Fig.2. Useful functionality of tablet PCs in an active learning environment. The green quadrant is provided for by a lecturer/instructors tablet PC. The blue part is provided for by student tablets.



Small scale (individual bespoke) use

With sufficient planning a lecturer with a tablet PC can implement an effective ALE session. A relatively simple way of achieving this is breaking the lecture up with exercises, tests, or peer review sessions on a student's tablet PC (e.g. Robson & Kennedy, 2013; Rawat et al, 2008). Price and Simon (2007) used this approach to pursue a social constructivist methodology, hoping to show students that direct verbatim notes are not adequate. The desired result was somewhat positive, but not conclusive. Enhanced mobility has also been cited as a benefit of the device. Using a wireless link to a data projector, lectures can achieve full mobility in the lecture theatre without loss of functionality (Goh & Calligan, 2013). Saving handwritten notes and sketches made on the slides and making them available to students after class via a VLE is also a very useful feature (e.g. Enriquez, 2007; Singhatanadgid & Sripakagorn, 2012), especially as it generates a record of the exact content discussed in the lecture. Lecturers can also take advantage of the inbuilt audio and screen-capture recording features in such devices to create supplementary voice-overs and videos to create further offline resources to further support the bottom right side of the learning cycle (e.g Furse, 2011). These will be of particular use for distance/ off-campus students. As established in the previous section, outside the lecture class these devices can also offer significant efficiency and time savings in terms of assessment marking through richer feedback (e.g. diagrams, flowcharts).

Issues for lecturers adopting any new technology in an existing course are how to best introduce the capabilities in a meaningful way. Integrated use of a tablet PC will often mean rebuilding a course from the ground up. Nevertheless, benefits can be made by thoughtful modification of existing material and delivery. One disadvantage would be the need to make similar annotations each time the course is run, but this is somewhat unavoidable given the nature of the task. Microsoft OneNote is commonly used throughout the literature since it possesses a lot of functionality for making and arranging notes and drawings, but it does not have the presentational output that PowerPoint offers. However, since there is little practical use in the majority of lectures having a presentational style, OneNote is possibly a better software tool when dealing with explanations of topics and developing system concepts and mathematics.

Large scale (department-wide) use

University education is quite varied due to the individual styles of each lecturer. Thus, for a fully consistent ALE experience departments/colleges/institutions must put in place a strategy to effectively propagate this kind of environment (c.f. Virginia Tech). The main barriers to an institute-wide distribution of tablets and establishment of an integrated tablet -based ALE across the board are the cost (equipment and time) and individual lecturer styles and resistance to change.

Whilst more consumption-orientated devices (Google Nexus, iPad, etc.) are now available at lower costs, feedback from students on their suitability has generally been poor, citing poor notetaking capabilities and a preference for full scale tablet PCs (Thomas, 2014) . Furthermore, the focus on consumption is likely to result in far more distraction than actual productivity in class; this would explain the difficulties of maintaining student on-task focus encountered by Romney (2015). Designing such an ALE is also fraught with tensions with respect to screen readability (compared to paper), limited battery life, and lost equipment. Some of these problems can be eliminated by combined digital and paper-based activities (Liao et al, 2008). There is an inherent issue with providing students the freedom of a digital device in a classroom environment. Students are known to be easily distracted, especially when digital and social media are easily accessible (Kraushaar & Novak, 2009). Perhaps then the e-paper style of devices, that lack the ability to access these distractions, would be more suitable for students. However, such a problem should ideally be addressed with social (re)conditioning not authoritative restriction , though this is clearly a much larger issue. Another common concern is the robustness of the wireless network between devices –if it fails it can grind the session to a halt.

Whilst additional time needs to be devoted to the planning of an ALE session, the extra preparation time is arguably justified by the benefits of the investments (Lord and Perry, 2006). However, this preparation time is often additional time required of lecturers so, if departments want staff to invest in improving lecture quality, they should be mindful of the extra pressures designing effective ALE sessions places on staff (Romney, 2015). Evidently, department-wide implementation is a considerable investment and needs to be supported sufficiently. The use of technology “champions”, who are motivated and engaged with the technology are very important in ensuring a broad, large scale ALE is successful.

Discussion: is there a real case for tablet PCs?

In this paper the author has attempted a comprehensive, but by no means complete, analysis of the current commentary on tablet PC use in engineering education. It is however accurate to say that the majority of the literature, evidenced by classroom-based experiments, is consistently positive in the improvements in engagement by students in classes incorporating tablet PCs. However, to address the elephant in the room: are these observations perhaps purely due to the novelty of the device compared to the more frequently experienced equivalent (PowerPoint presentations)? Were tablet PC use more prevalent, would it be as engaging to students at the same level as observed in studies? Some works have attempted to show improvements in the performance, and thus ultimately the grades, of students in classes that incorporate tablet PCs. Some small scale studies (e.g. Sutterer and Sexton, 2008) found no significant improvement in students final scores compared to a traditional didactic lecture course. Both Ellis-Behnke et al (2003) and Enriquez (2007) report statistically significant improvements throughout class and exam performance, but only report these for a one-year period. There needs to be more longitudinal studies to conclusively inform the effectiveness of tablet PCs in contributing to assessment performance.

The majority of studies to date have been undertaken with surveys and questionnaires from staff and/or students. Whilst useful there are inherent limitations and oddities with such methods, no less in terms of comparability between different studies. Regardless, the improvements observed in inclusivity of learning styles and student engagement that tablet PC-orientated sessions can produce is perhaps enough to make its use warranted. The use

of tablet PCs in facilitating an ALE for students who respond more positively than to a conventional lecture was demonstrated across many examples in the literature. However, tablet PCs are not essential to achieve this kind of environment. Collaborative Project-Based Learning, for example, is a popular name for project-focused student group activities that try to incorporate multiple instructional strategies. Whilst tablet PCs can support these greatly, they are not crucial in achieving the desired results (Water-Perez and Dong, 2012). A mandatory device policy for students could be excluding to those students from disadvantaged socio-economic backgrounds and those with computer-operational disabilities. Subsidy schemes and study needs agreements could be way of alleviating this and possibly entice students to enroll.

Similarly for CMS software: a lecturer at the College of Engineering at Boston University implemented a crude (and not real-time) ALE using student submissions to Dropbox and Google Docs (Romney, 2015). This example highlights that personal aptitude of software and communication systems plays a significant part in the viability of different ad-hoc methods. A properly integrated, department-wide ALE policy is therefore a significant training investment. However, just as students have their own preferred learning styles, lecturers too have their own preferred learning and lecturing style. Attempting to force lecturers to use technology they are not comfortable with will not elicit the possible benefits.

Equally, caution must be raised in over-use or poor implementation of novel and quaint technologies. Kandiko & Mawer (2013), in their study, point out that students are generally not concerned with pedagogical benefits of technology, or innovative uses in teaching, caring instead for more contact time and functional, efficient IT resources. Poorly thought through distribution and implementation in a curriculum will likely lead to limited usage (see for example Burke et al, 2005). An interesting question to consider is which group of students (first/last year) would benefit most from tablet PCs?

Conclusions

It is clear from the literature that tablet PCs are favoured almost universally in terms of student engagement and active learning they promote in a lecture session. From reviewing the literature this paper has identified the suitability and best practices of using tablet PCs to facilitate active learning environments. Using simple modifications of existing lecture material and incorporating the feature offered by e-ink devices is sufficient by an individual lecturer in improving the engagement, and hence learning process for students. When the capabilities of a wireless tablet device are leveraged in an integrated, department-wide manner, the effect on students' perception and education can be transformational. Some of the issues and barriers to implementation were also discussed in this paper and are hopefully of use to other academics and policy makers.

Given the complexity of many engineering problems addressed, particularly in final year courses, the greater flexibility of delivery, greater interaction, and engagement is of great benefit to both lecturers and students. The capabilities discussed here possible with a tablet PC (and other technology in general) is perhaps key in shifting the role of the lecturer

from an instructor, to a facilitator, of learning. This is however only realizable if the implementation is managed and implemented well.

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