Paperless classrooms: a networked Tablet PC in front of every child

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i-Pads in front of the children in networked classrooms have the potential to transform learning. In mathematics particularly, interaction by screen-touch using fingers or stylus seems preferable to keyboard and mouse. Their portability and reliability, so that children can take them home, and their potentially low price, are other attractions. It is proposed that, to maximize their potential to improve learning, the Tablets should be configured so that they emulate workbooks - combining textbook, exercise book, test-paper and progress record - and be embedded in a school-wide managed learning environment that combines effective learning management support for class teachers with safe-keeping of students work and records.

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Introduction

In an earlier paper (Osmon 2011) I predicted the imminent popularity of iPad-style Tablets among schoolchildren and their potential for organised use in classroom learning. Since then iPad sales have been booming and other well-known IT brands are now competing with Apple, and I have found descriptions, in the form of patent applications, of relevant learning systems.

Networked classrooms with i-Pads in front of the children have the potential to transform learning. In mathematics particularly screen-touch interaction using fingers or stylus seems preferable to keyboard and mouse. Portability and reliability, so that children can take them home, and their potentially low price, are other attractions. It is proposed that, to maximize their potential to improve learning, the Tablets should be configured so that they emulate workbooks- combining textbook, exercise book, test-paper and progress record- and embedded in a school-wide managed learning environment that combines effective learning management support for class teachers with safe-keeping of students work and records.

Workbooks and e-Workbooks

Traditionally, in the UK, school-children write their work in exercise books: ruled with lines or, in the case of mathematics, ruled with a grid of squares and a textbook, alongside the exercise book, provides instruction and specifies exercises to be done. Besides serving as a place of *interaction* with work in progress, the exercise book *records* work done. For reasons of economy, photocopied exercise sheets, or exercises copied from the board, are sometimes substituted for textbooks. Workbooks- cheaply printed combinations of text and exercise book- are a more reliable alternative to supplementing exercise books with loose leaf material. They are more common in the United States than in this country. Workbook pages formatted with printed questions with space for answers have something in common with test papers.

Emulations of workbooks or "electronic workbooks", or e-Workbooks as I shall call them in this paper, potentially offer some advantages over pencil-and-paper workbooks. For example they are paperless and hence may provide more reliable and convenient recording of work done than paper workbooks and they can reduce the administrative burden on class teachers since individual learner data (work attempted, dates, and marks) held in electronic form in individual workbooks is readily copied automatically into class records, particularly if the workbooks are *networked*.

Currently, the closest approximation in most UK schools to networked e-Workbooks is the PC-lab. However, for *cost* reasons, classes typically have limited timetabled access and learners work in pairs. In these circumstances benefits are modest.

There are other reasons, besides cost, why e-Workbooks have not been adopted more extensively. Thus, paper workbooks are highly *portable*, they can be read anywhere, any time, without requiring access to a PC, and perhaps a broadband network connection. This means all learners can take them home to continue working, not just those with broadband at home. And, for many purposes, pen or pencil is more appropriate for *input* than a keyboard and mouse.

Paperless classrooms

There are published proposals/accounts from the US of more extensive use of e-Workbooks. Two of these (Dockterman 2006, Stuppy 2007) describe highly controlled and very specialised, paperless e-Workbook learning environments: what we would might call 'crammers', attended by students for intensive remedial courses in basic arithmetic. All the inputs of students, including their working, are recorded so as to provide a detailed account of progress. Additionally the networking allows a teacher to *monitor* in detail, by viewing on her screen, the work of individual learners in her class, in real-time, so that she may intervene promptly with assistance when necessary. Interestingly, based on initial assessments, the students may be assigned *individualised learning* programmes, or initial "student profiles". The networking allows their marks to be extracted and recorded and compared with expectations in their profiles, which may then be modified, and future learning tasks allocated accordingly.

Another interesting aspect of networking in these accounts of paperless classrooms is reference to the use of copyright learning materials and automatic debiting of students' accounts when their workbooks receive *downloaded instructional text*. In a paperless world textbook publishers will doubtless seek such new ways of maintaining their revenue streams.

In these accounts there is nothing especially innovative about the learning materials presented to students. What is interesting is how the details of their interactions are visible to the teacher, and may be timed and recorded. Also, learning is evidently a more intensive experience for the learners than in a traditional classroom. And, *support for the teacher's role*: real-time access to students' efforts, semi-automatic management of individualised learning programmes, automatic recording of students' progress and record updating, ensures nearly all of her class time is available for actual teaching.

These accounts relate to highly controlled and specialised learning environments and, at least while the networked e-Workbook technology available in our schools is the familiar PC-lab, paperless classrooms, with their potential for supporting teachers, are unlikely to become the norm across the wide range of subjects in the curriculum

Tablets and e-Workbooks

In principle, the adoption of networked classrooms by schools, with an e-Workbook in front of every child, could offer a range of educational benefits arising partly from the interactivity of the workbooks and partly from the communication opportunities presented by networking and partly from the ability of the technology to record learners' progress.

However, several barriers to adoption of PCs as all-purpose platforms for implementing e-Workbooks are apparent: cost, keyboard-and-mouse as the principal data-input means, and lack of portability. Tablet PCs (i-Pad clones) are preferable as e-Workbook platforms under all of these headings. In the rest of this section I address the cost issue.

When the market is highly competitive and supply can match demand, price tends towards manufacturing cost. These conditions are not yet met for iPads and their clones but because of their relative simplicity of design, compared with netbook PCs (most obviously the absence of rotating storage, keyboards and multiple connector sockets), we can expect unit prices to fall with a year or two- from around £400 towards £100- when production ramps up to meet or exceed demand and there is more competition, greatly undercutting PC prices. But, cost-of-ownership is not just purchase price. Product lifetime- which depends on reliability- is also a factor, and ease of use reduces the need for technical support. iPads appear to be superior in these respects too.

Overall costs for a school going paperless depend on the system architecture and this includes: wireless networking, school server, broadband connection to the internet, and of course the system software to integrate these. Many schools will have wireless networking in their classrooms already along with the other elements of the system. However, it seems unlikely that the current generation of "integrated learning environments" will be adequate to support paperless schools with a Tablet in front of every child. A later section discusses such architectural issues and how they may be resolved.

e-Workbooks for learning in various subjects

Tablets are multimedia devices- aural input and output, equipped with cameras and with the ability to show video clips- and not merely a paperless alternative to pencils and exercise books and printed textbooks. However, multimedia learning materials for Tablets are unlikely to appear overnight, and certainly not meeting needs across the whole curriculum. It seems likely therefore that the first e-Workbook "Apps" will be derived from existing paper-based learning materials, and at least one company (Inkling 2011) is already offering education publishers a service. According to chatter on the Internet, McGraw-Hill are already clients and Pearson are negotiating.

Different subjects are likely to use the multimedia capability of e-Workbooks in different ways. And these subject-characteristic ways will take time to develop, as teachers and the authors and publishers of learning materials become more aware of the potential of Tablets. For example, language learning would surely benefit from their multimedia capabilities: we can readily envisage a language class of children, with each child immersed in dialogue in her personal language lab. A project at Tufts University (Tufts 2009) emphasises the learning possibilities of real-time interaction with the physical world. Engineering applications are described but applications in science would also be feasible. The potential of Tablets for supporting learning across the curriculum will surely hasten their adoption.

e-Workbooks for learning mathematics

Touch input (fingers and stylus) is better for doing mathematics than keyboard and mouse. This is because mathematical language employs a range of mathematical symbols, including oversize characters, not readily accessible from a keyboard and because of the non-linear syntax of mathematics language. Doing mathematics also involves drawing shapes, building tables, making charts, and plotting graphs, all of which are potentially easier with touch input. Certainly touch input with a stylus is more like drawing with a pencil on paper so that Tablets make a better bridge to traditional mathematics classroom working than PCs with keyboard and mouse.

The traditional pencil-and-paper tool for learning mathematics is a *grid-of-squares exercise book*, not just in Britain but in many countries worldwide. There are good reasons for the ubiquity of the grid-of-squares, including its support for mathematical language (learning the symbols and syntax) and facilitating orderly presentation of mathematical expressions, and mathematical working.

We can envisage a Tablet screen displaying a grid of squares- and looking like a page from a traditional mathematics exercise book. Emulating this traditional platform should give comfort to parents and teachers who may struggle in a new world of paperless learning! Besides its traditional merits, the grid of squares is potentially a rich base for interactive mathematics learning: we can suppose the grid indicates a basis set of data structures: *arrays* of: *cells* containing symbols (e.g. characters, tiles carrying icons), *line elements* (horizontal and vertical), and *points*- where grid lines intersect.

Then, touching a screen location points to a particular element of one of these arrays so that, for example, by touching the cells a child can push tiles around to assemble shapes- blocks of tiles- on the grid of squares, to use for developing counting, etc. Tablet touch-screens are a medium that offers a more flexible and intense learning experience than working either with physical tiles or pencil and paper and working with tiles like this seems to have great potential for developing primary mathematics knowledge, whether in obviously mathematics learning contexts like counting and adding and multiplying exercises or by using tiles on a grid of squares as the basis for constructing a whole range of board games and puzzles on the screen. A computer science master's student at King's is aiming to demonstrate this potential in her project.

We can envisage the range of operations available to learners increasing as they progress: writing symbols (aided by symbol recognition) and pasting them into a mathematical expression then syntax checking the expression and then evaluating it, constructing tables from data semi-automatically and then displaying graphically using different degrees of zoom, and so on. The multimedia capability of Tablets has less obvious potential in mathematics than some other subjects. In all subjects there may be advantages to specifying tasks using voice instead of or as well as text. Demonstration examples of procedures, and proofs, feature strongly in traditional mathematics teaching. Tablets can do better than present them statically as on the printed page: recordings, with commentary, that can be replayed step-by-step may prove a helpful way to learn.

System architecture

Putting Tablets, with learning Apps installed, in front of children may well not be sufficient for them to gain significant learning benefit. Preferably the Tablets should be configured so that they emulate workbooks- combining textbook, exercise book, test-paper and progress record- and are embedded in a school-wide systems architecture that stores students work and serves three kinds of user:

(a) Learners (the children) who will need to:
Read (including observe or listen to) learning material stored in their workbooks; *Interact* with this learning material (interactions recorded); *Read* their earlier work and teacher's feedback.

(b) Class-teachers who will need to:
Distribute learning materials to the children's Tablets, either individually, to groups, or to the whole class; *Monitor* the work of individual children, in real-time and also periodically for marking and progress review; *Record* the awarded marks and other progress review data in each child's workbook and also in a whole-class record.

(c) Director (maybe head of department or head teacher) who will need to:
Monitor the progress of individual teachers and learners.

Besides these internal users there will be external ones: authors and publishers of learning materials, and also examination boards. Processes will be needed so that the school can select and install learning materials and examinations can be conducted via the school server and the children's workbooks.

i-Pads are probably more reliable than PCs, but not perfectly reliable, and inevitably children will occasionally lose or break them. i-Pads have quite large, but not unlimited storage. The systems architecture can overcome these limitations and ensure learners' records are *complete* and *secure*. To this end three layers of stored data are envisaged: Individual workbooks, School Server, Secure Data Repository. The storage role for each layer is as follows. Individual's workbooks store the data in recent and current use, including a record of the user's interactions, and also newly downloaded data intended to be used soon. The School Server has storage capacity greater than all the Tablets in the school and contains a copy of the data currently stored in every Tablet, and data likely to be needed soon- such as next chapters from textbooks. The Repository stores a copy of the data currently held in the server as well as all earlier data.

The three layer storage mechanism works as follows. Copies of data move down on demand from users, and newly entered data moves up, after a while, if it is not being used. During the school day, the record of work done during that day, or done previously at home, gets automatically copied from learners' and teachers' workbooks to the School Server, and from time-to time relatively old data is moved up to make space for new- but old data is always accessible on demand, albeit with some delay. (NB no data is ever destroyed or altered- though amendments may be appended- this is feasible because secure bulk storage is so cheap.)

The Tablet market is divided among at least four operating systems: Apple (iPad), Google (Honeycomb), HP (Touchpad), and Microsoft (Windows 7). A common platform for workbook emulation would be very helpful.

Challenge of e-Workbooks for mathematics examiners and researchers

Paperless classrooms make paperless examination rooms feasible. In principle, mathematics tests can be downloaded into the School Server over the Internet by the

Examination Board, and then downloaded into individual learner's workbooks and only become visible at the time the examination is due to start and, at the end of the allotted time, be whisked away for marking.

Teaching and learning for the test has been a baleful influence on mathematics education. If learners' work is indeed recorded securely and in detail in their e-Workbooks, as proposed in the model systems architecture above, then reviewing these records would be a form of coursework assessment and might be a better kind of testing.

The proposed systems architecture automatically records the work of whole classes in great detail. This means cost-free collection of data where the work is part of a research investigation- surely a challenge to mathematics education researchers to devise materials for the children to work with that have potential to illuminate their difficulties with mathematics.

Conclusions

Reports of paperless classrooms using workbooks in highly controlled situations suggest they have potential to offer a more intensive learning experience, with teachers spending more class time actually teaching. e-Workbooks based on Tablets can have many of the positive characteristics of pencil and paper for mathematics learning plus benefits arising from interactivity and communication. And it seems major educational publishers are preparing tablet-compatible learning materials. I have proposed embedding networked Tablets in a school-wide systems architecture to maximise their potential to improve learning across the curriculum and also to protect users from any shortcomings. Progress may be slowed by absence of a common platform for e-workbooks across tablet operating systems. Much of its potential is waiting to be explored but it already seems that the Tablet may become the principal learning tool in mathematics classrooms.

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