Do-it-yourself e-Exams

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This paper focuses on a small case study in which we developed and tested a set of spreadsheets as a 'do-it-yourself' e-examination delivery and marking environment. A trial was conducted in a first-year university level class during 2017 at Monash University, Australia. The approach enabled automatic marking for selected response questions and semi-automatic marking for short text responses. The system did not require a network or servers to operate therefore minimising the reliance on complex infrastructure. We paid particular attention to the integrity of the assessment process by ensuring separation of the answer key from the response composition environment. Students undertook a practice session followed by an invigilated exam. Student's perceptions of the process were collected using pre-post surveys (n = 16) comprising qualitative comments and Likert items. The data revealed that students were satisfied with the process (4 or above on 5-point scales). Comments revealed that their experience was in part influenced by their level of computer literacy with respect to enabling skills in the subject domain. Overall the approach was found to be successful with all students successfully completing the e-exam and administrative efficiencies realised in terms of marking time saved.

Keywords: computerised assessment system, e-exam, spreadsheets.

Introduction and Background

In this study we set out to answer the research questions of: a) could a spreadsheet be used as a small-scale, secure, do-it-yourself exam delivery system? And, b) would students accept this approach?

This small exploratory case study is about using a spreadsheet as a response collection medium for computerised exams. This represents an interim step within a wider effort (Fluck & Hillier, 2016; Hillier & Fluck, 2017). This case is informative in terms of what can be accomplished without access to a corporate e-Assessment infrastructure. In Australia, the authors are members of an Australian Government funded project "Transforming exams: a scalable examination platform for BYOD invigilated assessment" that is investigating approaches to the development of authentic high stakes computerised assessment in higher education. The lead author and colleagues have previously articulated a range of conditions for the deployment of an e-Exam approach (Hillier & Fluck, 2013) and potential benefits linked to deploying e-Exams (Fluck & Hillier, 2016) in terms of facilitating curriculum reform towards the use of more authentic (Mueller, 2016) and relevant assessment. Jamil, Tariq and Shami (2012) also agree that using computers for assessment can improve learning by testing skills, knowledge and capabilities relevant in the twenty-first century. Although the broad aim of our work points to authentic assessment, this paper is not about it per se. Rather we focus on one method for using spreadsheets as a delivery mechanism for exams and its acceptance by students.

The spreadsheet was deployed within the open source e-Exam delivery platform developed as part of the 'Transforming Exams' project. Although the platform is not required in order for the spreadsheet elements of the approach to function, the e-Exam system used in this study provides a secured and consistent operating environment when used to boot bring-your-own laptops or desktop computers. Hillier and Fluck (2017) explain that the e-Exam platform is a modified version of the open source Linux operating system and a full office suite (Libre Office) on board a 'live' USB stick. The spreadsheet-based testing approach in this paper adds to the stock of existing methods developed under the 'Transforming exams' project that has included the use of word processors, multimedia, software programming and maths tools.

We will next review the literature related to prior work done on the use of computers for exams with the aim of developing a set of requirements for a do-it-yourself e-exam delivery approach. An overview of the study design and then details of the procedure used to develop our solution is then presented. Results from a live trial of the approach are presented that includes surveys of the student's experience and a discussion of the implications of this work.

Literature

The use of computers for testing in education has been occurring since at least the 1960s with Swets and Feurzeig (1965) writing about formative uses in medical, mathematical and language teaching. In the intervening years little progress has been made in bringing technology into the mainstream exam halls of universities where pen-on-paper exams still dominate. However, over the last 10 years there has been a substantial increase in interest from educational institutions to move away from pen-on-paper testing towards the use of computers for exams.

The recent development of approaches to e-exams has been written about by a number of researchers. We focus on efforts where the aim of enabling authentic assessment has been apparent in the approach taken. Fluck, Pálsson, Coleman, Hillier, Schneider, Frankl and Uolia (2017) discussed several exam solutions being developed and used in Europe. At the University of Iceland local area network drives have been used for e-exams since 1998. At ETH Zurich the open source Safe Exam Browser (SEB) suite of software is used with Moodle and ILIAS and is now used by numerous educational institutions around the world. In Austria at the University of Alpen-Adria at Klagenfurt, the Secure Exam Environment (SEE) system was created in 2011 (Frankl, Schartner & Zebedin 2012). SEE uses student owned laptops that are started from a network-based Linux operating system image (net-boot) that then connect through to the university's Moodle LMS via Safe Exam Browser. In Finland all universities have access to use the "eXam" system, constructed by a consortium of Finnish universities in 2017. Students use a web browser on institution owned computers that are housed in specialised video monitored 'aquarium' rooms (Kuikka, Markus & Laakso, 2014).

Other reports of e-exam developments include those by Tamm, Lattu and Lavonen (2016) in Finland, Alfredsson (2014) in Iceland, Walsh and Keiller (2014) in South Africa and Bussières, Métras and Leclerc (2012) in Canada. However, such developments are not without their risks. In USA, ExamSoft is a commercial provider that offers as an option use a BYO laptop to students taking the state Bar (law) exam in most states. In July 2014 a major glitch caused problems for multiple state exams running at the time resulting in law suits from impacted students (Associated Press, 2014; Straumsheim, 2014). This highlights the delicate nature of high stakes assessment and the need to construct robust technology.

Students have also been asked their thoughts regarding the computerisation of exams. In the UK Dermo (2009) reported on a survey of student perceptions of using the QuestionMark perception test tool at the University of Bradford. In Australia, Hillier (2014) surveyed 488 students on their pre-conceptions of using computers for exams. In general students were cautiously positive, with differences emerging between disciplines, perhaps linked to the nature of assessment tasks typically used in those areas and their level of risk acceptance around the possibility for technology failures impacting their exam.

The many solutions outlined so far all have one thing in common – they require networking infrastructure and online servers to function. In most of the above cases a live network must be functional for the duration of the exam but a network outage, even if only brief, will interrupt student's work in the exam. The avoidance of a 'single point of failure' during critical times (as seen in the ExamSoft case) should be a priority in designing a high stakes e-exam delivery system.

Many existing exam delivery solutions are largely beyond the reach of individual teachers and small education organisations to deploy in contexts where networking may be unreliable, or where IT support may be limited. The ability for individual teachers to independently utilise technology to improve their work without the prerequisites of a large institutionally supported infrastructure democratises the benefits of technology. Common tools such as a software office suite and specifically spreadsheets are powerful 'mind tools' (Jonassen 1991) that can be deployed to enhance education. In this same light, software can serve as human capability multiplier. This has benefits in both efficacy and efficiency of education. Software applications are frequently 'tools of the trade' in many disciplines and workplaces. Using a spreadsheet as part of the learning and assessment environment can allow assessors to improve the authenticity (Mueller 2016) of the assessment tasks they set. Provided e-tools are designed with ease of use in mind and that teachers are equipped with the prerequisite knowledge, then efficiency in the education process itself can be realised. This is significant for many time poor educators. Arguably this allows teachers to spend less time on administration and instead focus their efforts on the creative endeavours of enhancing curriculum and teaching activity.

Education practitioners have already developed spreadsheets that can automate assessment activity. Freney, Wood, Ellwood, Lewis and Muller (2010) developed an online toolset for marking and feedback in the form of an online gradebook that also came with a basic spreadsheet file for off-line use. Hillier's (2012) 'Excel-e-mark' extended their work into a set of scripted Microsoft Excel workbooks that did not require an Internet connection to function. Brandriet and Thomas (2015) outlined a spreadsheet tool that can be used by teachers to analyse their student's responses to the American Chemical Society Examination. Hayes and Bee (2008) designed a spreadsheet to summarise and tally grades exported from an LMS. While these tools are useful once a student's work has been submitted, the spreadsheets were not designed as an assessment environment in which students could compose their responses.

The idea of using spreadsheets as an assessment environment has been explored by others. Bradley (2013) explains how to create a simple multiple-choice quiz using Excel, but this requires manual processing of each submitted file. Blamey and Freeman (2004) created a sophisticated spreadsheet for individualised problem-based learning in a financial accounting course that included self-assessment and summative assessment of submitted student files. However, both these techniques entail hiding correct answers within the spreadsheet file that is in the hands of the student. This idea equates to 'security by obscurity' which is not well regarded (Scarfone, Jansen & Tracy, 2008). While this may be satisfactory for formative assessment, this raises the risk of cheating by copying or hacking when used for summative assessment. Therefore, if the components that determine the grade can be removed from the response composition environment then a greater level of security can be achieved.

Based on the review of the literature it would appear the use of spreadsheets that combined both an assessment environment and a marking gradebook into a single solution were scarce. The review also bought to the fore some concerns that we were motivated to address in our solution. These form sets of guiding requirements:

- Utilise standard and common spreadsheet software (leverage existing tools, minimising barriers for use by teachers and students)
- Enable automated or semi-automated marking of selected response style questions and short text responses minimising manual data entry (to realise work efficiencies of technology and minimise errors)
- Not rely on a live network during the exam (to minimise the chance of disruption and enhance teacher autonomy)
- To avoid hiding the answer key in the student portion of the system (to remove the chance a student could hack their way to the answers).

Method and Development Approach

In our development effort we focused on how we could adapt common office software, specifically a spreadsheet, for use in supervised summative assessment. The aim was to produce both an assessment response environment and an automated grading tool that would be robust and secure.

We drew on lessons learnt so far with respect to the logistics of running prior bring-your-own laptop-based e-exam sessions using the previously developed Linux bootable USB e-Exam system (Hillier & Fluck, 2017, and transformingexams.com). The e-Exam system has previously been used for offline word processor based exams (Hillier, 2015; Hillier & Lyon, 2018a,b). The procedure we followed to develop, test and refine the spreadsheet tool set is outlined below. The study was covered by the ethics approval previously gained for the e-exams trials already being conducted as part of the broader Transforming Exams project.

1. We called for expressions of interest from students enrolled in a first-year introductory Chinese language class. This class was selected because existing assessment comprised a mix of selected response and text based constructed responses.
2. A prototype of the spreadsheet toolset was created with three components:
   a. The question and response spreadsheet which did not contain any grading functionality. Each student used their own copy of this file during the exam (within Libre Office Calc, loaded onto an e-Exam USB flash drive). See Figure 3 for an example.
   b. The 'gradebook' spreadsheet containing the response and answer keys used to assign grades for each question (used with Microsoft Excel). See Figure 2 for details.
   c. The 'combine' spreadsheet file that used the 3rd party RDBmerge 'add-in' (de Bruin, 2013) for Microsoft Excel. This was used to merge data sets from individual student response files into the gradebook spreadsheet.
3. A 'practice exam' was conducted with the group of students who had expressed interest in typing their examination. The session was conducted in a collaborative learning computer suite quipped with group tables, electricity supply points and several desktop computers. Students used their own laptops in the first

instance with back-up provided by institution owned laptops and in-situ desktop computers. This session served multiple purposes:
   a. To test the proposed exam format and configuration of the student facing spreadsheet software.
   b. To ensure student's laptops would work with the Linux Bootable USB e-Exam system. If not, a back-up laptop was lent to the student.
   c. To provide students with an opportunity to practice the software start up process, to preview the working environment and try the question formats.
   d. To provide the researchers with the student's initial impressions of the process and software.
4. We collected data during the practice exam session via a pre-exam survey completed by the students (see Table 1), by observation and by system logging features of the USB e-Exam system.
5. Following the practice session, the academic tested the process to be used for merging and marking the responses based on the practice exam data responses.
6. We then adjusted the spreadsheet software. Improvements were:
   a. Changes to the layout of the exam on the screen to ensure it would fit horizontally on one screen.
   b. Setting all non-editing cells to 'protected'. This prevented accidental damage to question content, prevent copying of question text and allowed students press 'tab' to move to the next answer box.
   c. The gradebook spreadsheet was updated to include a wider range of alternative responses using wild cards and different response patterns along with partial marks for each.
7. The exam was prepared using the updated spreadsheets. The gradebook spreadsheet used one column for each question. Sets of expected responses and corresponding marks were entered.
8. The exam event was conducted in the same room as the practice session. Students were lent an institution owned laptop only where their own did not work. The procedure in the exam room was:
   a. Upon entering the exam room each student received an instruction sheet, the post-exam survey and an e-Exam system USB containing the exam spreadsheet.
   b. Each student then booted their laptop using the e-Exam system USB. A technical helper was on hand if required. All students then waited for everyone to be ready.
   c. At the 'e-exam starter' screen students entered their student ID and name.
   d. At the appointed start time the invigilator asked students to begin.
   e. The system then opened the spreadsheet containing the questions and spaces to write responses.
   f. Students typed responses into the spreadsheet. The file was automatically saved every 2 minutes.
   g. When complete, students saved their file, shut down their laptop and handed back the USB that now contained their responses.
   h. Students then completed the post-exam survey prior to leaving the room.
9. Following the exam, response files were retrieved from USB sticks via a large USB Hub. The files were then processed using the 'combine' spreadsheet via the RDBMerge Add-in within Excel. The table of collated student responses were then copied into the prepared gradebook ready for marking.
10. Marking then occurs via embedded formulae (see figure 2) in the 'results table' sheet within the gradebook spreadsheet. Marking took place automatically for selected response questions. Short text responses were iteratively marked. A new correct or partially correct response could be added to the answer key on-the-fly. Wild card characters or alternate wordings were possible. Corresponding mark allocations were then added to the key. The formulae embedded in the gradebook then evaluated responses for that question from all students against the updated marking key. This process continued until all correct variations were included. Any remaining responses not found in the answer key were allocated a mark of zero. It was also possible to add incorrect responses to specify negative or zero marks. As marking progressed efficiencies accrued with each possible response added to the key.

The steps above are broadly representative of a typical cycle for use of the e-Exam system when using spreadsheets without a live network. This workflow is depicted in figure 1.

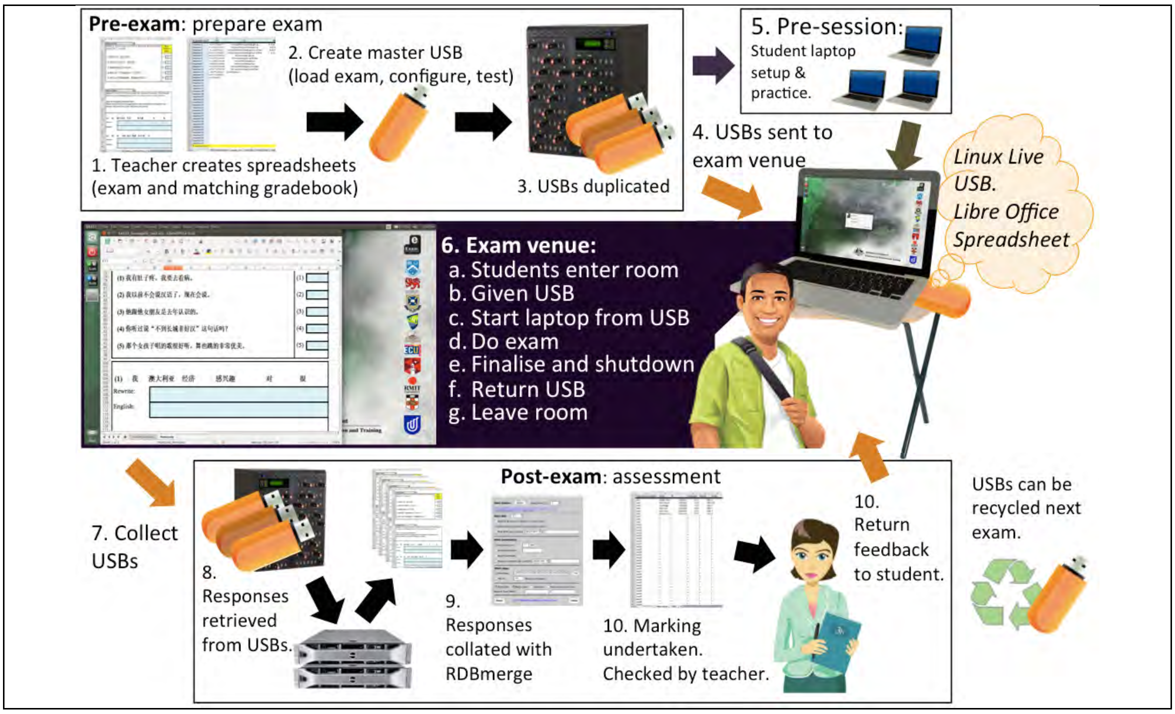

Figure 1: Offline e-Exam workflow using spreadsheets

Figure 2: Marking process in the gradebook spreadsheet

Data Analysis

Following the trial, we analysed the pre and post survey responses (n = 16) shown in table 1 using SPSS v24. Likert item data were considered to be non-parametric (Jamieson, 2004) with Mann & Whitney's (1947) U test used to check the variance of two groups (males and females). The study by Dermo (2009) supports the choice of using non-parametric tests when analysing students' perceptions of e-assessment systems. In terms of the pre-post paired Likert items, we used the 'Sign Test' to check for differences (Roberson, Shema, Mundfrom, & Holmes, 1995). Note; the requirement of a Wilcoxon Signed Ranks Test (Wilcoxon, 1965) of normal distribution of differences was not met with Shapiro & Wilk (1965) test (p = .001). It is also noted that the small sample could have impacted the accuracy of the results due to the dropping of 'ties' in the analysis (Mendenhall, Wackerly & Scheaffer, 1989). However, like Demo (2009) we do not consider the data to represent an objective truth but rather are indicative of the strength of the opinions of this particular group of students. As such we applied the statistical techniques to Likert items as one means of sense making the body of opinion in conjunction with analysis of open comment questions and observation.

Findings and Discussion

The group of first year undergraduates comprised 17 individuals at the practice session. One student did not type the exam so was excluded (n = 16). This small sample means that the statistical findings cannot be generalised beyond this group.

Students reported a positive experience of using the spreadsheet-based e-exam with most questions ranking above 4 on a 5-point scale (where 5 is most positive) on both pre and post surveys (see Table 1). When we compared their pre and post opinions using the 'Sign test', there was very little change (note missing values were dropped based in pairs). Only one item "It was easy to start my computer using the e-Exam USB stick" saw a significant drop in agreement from 4.7 to 4.1 in the post (p = .03) perhaps due to stress at the start of the exam. However, our anecdotal observation was that the start-up time was considerably less in the exam compared to the practice session.

Table 1: Survey items

Likert items	Pre survey			Post survey			*M*	Sign test
(Strongly Agree 5, Neutral 3, Strongly disagree 1)	*n*	*M*	*SD*	*n*	*M*	*SD*	Diff.	*p.*
The written instructions were easy to follow	15	4.3	0.60	16	4.3	0.58	0.0	n/s
It was easy to start my computer using the e-Exam USB stick	16	4.8	0.45	16	4.2	0.83	-0.6	0.03
I can use the e-Exam system just as well as my own laptop	16	4.0	0.97	16	4.2	0.54	0.2	n/s
It was easy to use the office suite (word processor / spreadsheet)	17	4.0	0.80	16	4.0	0.73	0.0	n/s
It was easy to save my response files into the correct place	10	4.5	0.71	12	4.2	0.39	-0.3	n/s
It was easy to answer the multiple-choice questions *	7	4.6	0.79	9	4.0	0.71	-0.6	n/s
I felt the e-Exam system was easy to use	17	4.3	0.47	16	4.2	0.66	-0.1	n/s
I felt the e-Exam system was reliable against technical failures	17	3.8	0.73	16	4.0	0.82	0.2	n/s
I felt the e-Exam system was secure against cheating	17	4.0	0.71	16	4.3	0.58	0.3	n/s
I now feel relaxed about using the e-Exam system for exams	16	4.1	0.62	16	4.2	0.66	0.1	n/s
I would recommend the e-Exam system to others	17	4.1	0.70	16	4.2	0.66	0.1	n/s

* This question was labelled with 'skip if not applicable'.

Each of the survey items (as listed in Table 1) were also examined for differences due to gender using a Mann-Whitney U test, however no significant differences were found (test results are not shown). The group comprised 7 females and 9 males.

In terms of logistics, while we did conduct our study in a room equipped with institution owned computers, we focused on a bring-your-own (BYO) laptop strategy in the first instance. Fluck & Hillier (2018) have argued that BYO is realistically the only financially viable approach if we wish to scale to a large number of simultaneous candidates. The combination of BYO laptops and institution computers did serve to increase the number of students that could participate. Both were booted from the live USB to provide a consistent software environment for all candidates. It is worth noting that should it be required, the spreadsheet elements of our work could also be deployed on institutional computer labs running Microsoft Windows or Apple OSX/MacOS, suitably configured for exams. However, this adds a dependency on IT support and networking.

The security feature of not including any 'answers' in the spreadsheet files used by students meant that there was zero risk of students being able to 'hack' their way to the answers. We did not find any instances of cheating in the exam and students rated it 4.3 out of 5 in terms of their agreement that "system was secure against cheating".

Relatively simple exam question types were used (multiple-choice, fill in the blank, True/False) along with short answer questions (see figure 2 for an example). The sophisticated features of the e-Exam software, such as multimedia or application based constructed responses were not in-play for this exam. This meant that the differences between doing the exam on paper and on a computer were less stark. However, students commented on the functional differences between paper and computer that pertained to the discipline context. Students contrasted the ability to hand-copy Chinese characters by visual recognition when using pen-on-paper and noted this was not possible when using the computer. A student commented:

> "Unable to copy and paste characters (like copying out characters by hand)."

Instead respondents needed to use one of the provided keyboard-based input methods (e.g. PinYin – see figure 2). Some students noted this as a reason for choosing to type the exam:

> "It's easier to type characters than to handwrite them. It is also neater." And "No requirement to learn how to write characters".

This may have implications for curriculum design and for student's approaches to assessment items in that a greater emphasis on Chinese typing and knowledge of PinYin will be required.

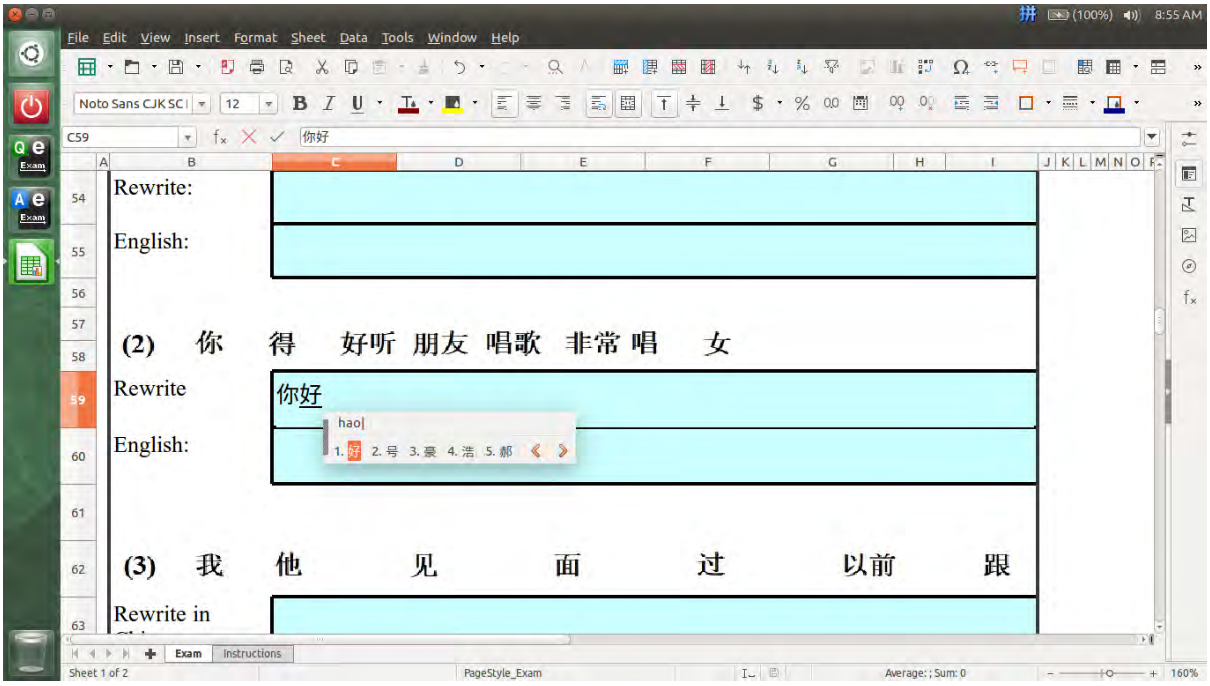

Figure 3: PinYin input within the e-exam spreadsheet

Chinese typing techniques may not be routinely taught to beginning learners and so this may need to be introduced earlier in courses where computerised exams are used. Similarly, a reduced focus on hand-writing due to e-exams may impact the value placed on it as a practice, such as for learning the stroke order for writing characters.

Conclusion

The spreadsheet approach outlined in this paper may suit use by individual teachers and smaller schools because there is no requirement for networks or servers. We argue that the barriers to getting started with e-exams are reduced by using common office software, everyday laptops, commodity USB sticks and where possible, free, open source software. Using off-the-self and open source components means it carries very little legal or financial overheads and only minimal infrastructure is required to run the e-testing approach. The approach is also flexible in that the spreadsheet components could be used in existing campus computer labs. For teachers with the knowledge of spreadsheet software the approach provides a degree of independence and flexibility without the need to coordinate with or rely in IT support services. However, at the current stage of maturity the approach does require some technology skills to administer, in particular the need to set-up the spreadsheet for each exam and to retrieve responses from individual spreadsheets following the exam. On a continuum from the least efficient manual pen-on-paper exams to a fully networked e-testing system, then this spreadsheet approach comes somewhere in the middle in terms of efficiency gains. In this case the administrative benefits were realised in terms of an electronic reticulation of questions, responses and marking. The marker estimated that using the spreadsheet saved about 30% of time it would have taken to manually perform all marking. This was due to the automatic assessment of some questions and the ability to iteratively add to the marking key in the case of text response items. The fact that text responses were easily legible in contrast to handwritten responses also saved time.

In terms of leveraging technology affordances, it was also recognised by us that we did not take advantage of the affordances of the spreadsheet software beyond using it as a digital data collection form. This was reasonable in piloting a proof of concept. The next phase of work should be to take advantage of the technological affordances of the spreadsheet for assessment design. Using simulation, data analysis and the mathematical functionality of a spreadsheet will be useful in disciplines such as maths, commerce and engineering. There were some hints in this study of the implications such a move could have on curriculum design. We noted that the move from a hand-written medium into a typed medium had implications for student's knowledge of Chinese typing input methods. In terms of beginners learning Chinese, this meant that there is now a greater reliance on knowledge of Pin Yin rather than being able to rely on direct visual reproduction of Chinese characters in order to produce a response. This brings assessment into alignment with authentic practice given the typed medium is now dominant in the work and social spheres.

However, our focus in this paper was on the viability of using a spreadsheet for exam delivery. Our experience was that it was successful with students providing positive feedback. Further technical work will be needed to refine the toolset in terms of usability, further automation and in demonstrating its use in other discipline areas. Providing user instructions, examples and training will also help other teachers to use the system proficiently and to help them develop more sophisticated assessments within the spreadsheet environment.

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