To type or handwrite: student's experience across six e-Exam trials

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This paper reports on student's experience of e-Exams as collected via surveys undertaken in conjunction with a series of optional live trials of an open source, bring-your-own-device (BYOD) based e-Exam system in six mid-semester undergraduate examinations during 2014 at The University of Queensland, Australia. A set of surveys were conducted prior and following each exam that covered ease of use, technical issues, comfort, confidence, time, typing versus handwriting prowess. Responses to Likert items were compared between those students who elected to type and those that handwrote their exam. Insights as to which issues proved significant for students will prove useful to institutions looking to implement computerised exams.

Keywords: e-exams, computer-assisted assessment, high-stakes testing, bring-your-own-device (BYOD).

Introduction

A range of drivers, issues and a rationale for the introduction of e-exams have been previously articulated by Hillier & Fluck (2013). Drivers include the increased use of computers in study, work and private life, near ubiquitous ownership of laptops by students reported as high as 94% by (2015), and the societal need for institutions to produce ICT literate graduates equipped with skills for the twenty first century (Binkley, Erstad, Herman, Raizen, Ripley, Miller-Ricci & Rumble, 2012). Issues include the provision of equipment for large, infrequent exam events, and if student owned devices are to be used, the diversity of student owned equipment and the high investment of students in their equipment. An e-exam system also needs to be easy to use when students are under stress, reliable and robust against attempts of misconduct. There is also a need to provide an equivalent exam environment for all candidates, while being reliable, sustainable, scalable for institutions to implement. Problems such as equipment supply, exam integrity, technical support, scalability and location need to be addressed with multiple possible combinations. For example, the dimensions of location and connectivity are mapped in Figure 1 to demonstrate that there is no perfect solution.

	On Campus	Distance
Online	• Space issues for institutions. • Improved exam management efficiency. • Equipment: need computer labs for 2000 at once. • More secure: it is supervised. • Needs reliable network. • Tech support more straightforward (if in labs).	• No space issue for institutions. • More efficient exam management. • Students supply equipment. • Less secure: students at home. • Needs reliable network. • Tech support more problematic.
Offline	• Space issues for institutions. • Less efficient exam management. • Equipment: need computer labs for 2000 at once. • More secure: it is supervised. • Network reliability not an issue.	• No space issue for institutions. • Less efficient exam management • Students supply equipment. • Less secure: students at home. • Network reliability not an issue.

Figure 1: The location and connectivity dimensions of the e-Exams problem

Authors such as Ripley (2007) and Fluck and Hillier (2014) also argue that a significant untapped potential exists in e-exams to remove a 'block' to curriculum transformation given that existing paper-based mode of assessment can be a significant driver of both learning focus by students (Ramsden, 1992, Gibbs, 1999) and a disincentive for teachers to reform curriculum. The potential of a comprehensive yet open architectural approach to computerised exams would greatly expand the 'pedagogical landscape' in the exam room. A computer enhanced exam platform capable of sophisticated constructed responses and able to provide the 'tools of the trade' used in professional practice will allow for much more authentic assessment tasks characteristic of a twenty first century problem environment (Binkley et al., 2012) to be set. Such tasks could include working though a complex financial simulation; using a medical diagnostic tool to work up a diagnosis; using computer aided design software to respond to a design problem by producing three dimensional engineering schematic; production of an example of contemporary digital art; carrying out a virtual experiment and analysing the results; and so forth. This approach contrasts to the commonly used paper-based exams that limit the range of assessment activities that can be undertaken in an exam room. Similarly, current approaches to the automation

of exam marking rely heavily on selected response, multiple choice style questions or provide an 'armoured word processor' that does little to move pedagogy forward into a twenty first century and instead largely replicate current paper-based questioning in a digital form (Fluck 2015).

An Approach to e-Exams

We have briefly outlined multiple dimensions that exist in developing an e-Exam solution. Looking at the issue of equipment supply, we argue that we should be making use of the large number of computers owned by students (Dahlstrom & diFilipo, 2013). The current high ownership rate of laptops by students at around 90% in the US (Dahlstrom & Bichsel, 2014) and a little higher at the author's own University at 94% (Hillier, 2015). An e-exam solution that uses bring-your-own devices (BYOD) for exams has been outlined by Hillier & Fluck (2013). Approaches to using BYOD also exist or are under development in Austria (Frankl, Schartner & Zebedin, 2011), Canada (Peregoodoff, 2014), Denmark (Nielsen, 2014), Finland (Lattu, 2014), Germany (Schulz & Apostolopoulos, 2014), Iceland (Alfreosson 2014), Norway (Melve 2014) and Singapore (Keong & Tay 2014).

As we transition from pen-on-paper to keyboard-based exams decisions made about the format, processes and technology to be used for e-exams will directly impact students the most as will strategies used to address change management, technology literacy and equity. Work by Dermo (2009), Frankl, Schartner and Zebedin (2012), Terzis and Economides (2011), Mogey and Fluck (2014) identified a range of student's concerns that include integrity (minimising 'cheating'); reliability (stability of the equipment and software to perform error free); familiarity (as to minimise the distraction the computerised environment so that candidates focus on the exam); efficiency (particularly when compared to hand-written exams); and psychology (the impact of stress and anxiety). This range of issues was used to develop a pre-project institution-wide survey reported by Hillier (2014, 2015) that looked at student concerns in the study context. The findings from the survey showed that the main concern related to fear of technology failure, potential for cheating and the resistance by significant proportion of students in moving away from familiar pen-on-paper exams despite issues such as messy handwriting and physical discomfort in longer exams. Overall, a majority of students claimed interest in being able to type responses to an exam with a mean of 3.3 on a 5 point agreement scale. Stronger interest was shown by students in Information Technology, Software Engineering, Education, Law, Commerce, Business and Arts. Those in pure Mathematics, Physics and Engineering programs such as Mechatronics, Civil, Electrical and Chemical thought that the assessments in their discipline would not suit computerisation given their use of long-form formulae and/or extensive use of diagramming in responding to assessments.

E-Exam Trial Design

The study reported in this paper was undertaken at the University of Queensland, a multi-disciplinary university in Brisbane, Australia serving 50,000 students. The institutional ethics committee approved all data collection processes and instruments used in the study.

This paper focuses on the second phase of the study in which live mid-semester exam trials were conducted in six courses. A pre-exam survey was conducted with students in set-up/practice sessions and post-exam surveys were conduced immediately following the exam session. The overall study design is depicted in Figure 2.
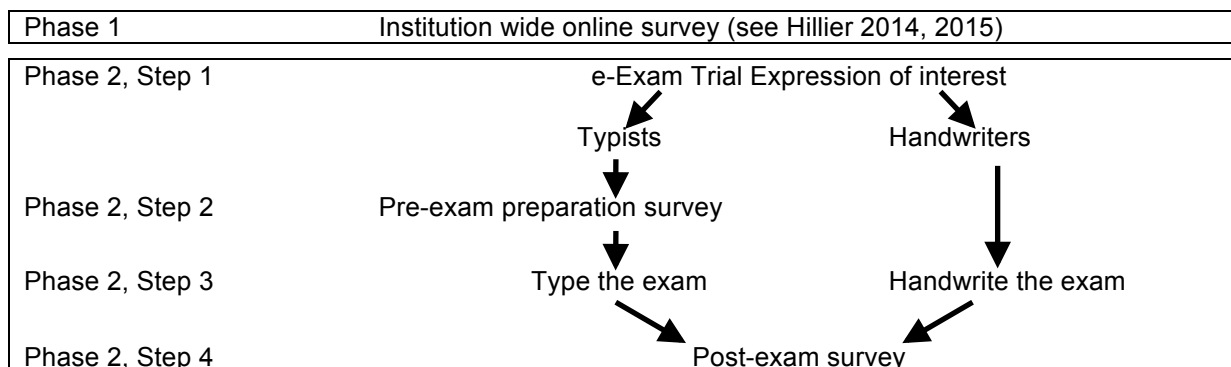
Phase 1	Institution wide online survey (see Hillier 2014, 2015)

Phase 2, Step 1   e-Exam Trial Expression of interest

Typists   Handwriters

Phase 2, Step 2   Pre-exam preparation survey

Phase 2, Step 3   Type the exam   Handwrite the exam

Phase 2, Step 4   Post-exam survey

Figure 2: Study design

The set of six e-Exam trials ran across six courses in 2014. Each trial was broken down into four steps. Students undertaking mid-semester examinations worth between 15% to 25% of the course grade were given the choice of typing or handwriting the exam. Despite a desire to more fully utilise the capabilities of the computerised

exam system, the choice offered to students directly impacted the nature of questions that could be used in the exam because questions had to work on both paper and electronic formats. The rationale for this choice was that of pragmatism. The findings from an earlier survey we conducted in the study context showed students were 'cautiously optimistic' towards e-exams (Hillier, 2014). Thus, we allowed a gentle introduction of a new approach to doing exams given the diversity of stakeholders involved and overall complexity of running exams (see Hillier & Fluck 2013). A mix of essay, short answer, table filling, diagram labelling and selected- response questions were used with suitable format adjustments made to cater for both paper and screen. See Figure 3 for a mock-up of typical questions.

Figure 3: Example question formats

Typists used their own laptop. Power sockets and spare laptops were provided in case of equipment incompatibility or failure. The final fall-back was pen-on-paper. The exam trial, depicted in Figure 4, required students to boot their laptop using an e-Exam 'Linux Live' USB storage device (Transforming Exams, 2014). The e-Exam USB contained a modified version of Ubuntu to prevent internet, bluetooth or local drive access along with LibreOffice (word processor) and a custom 'exam starter' that guided students to begin the exam.
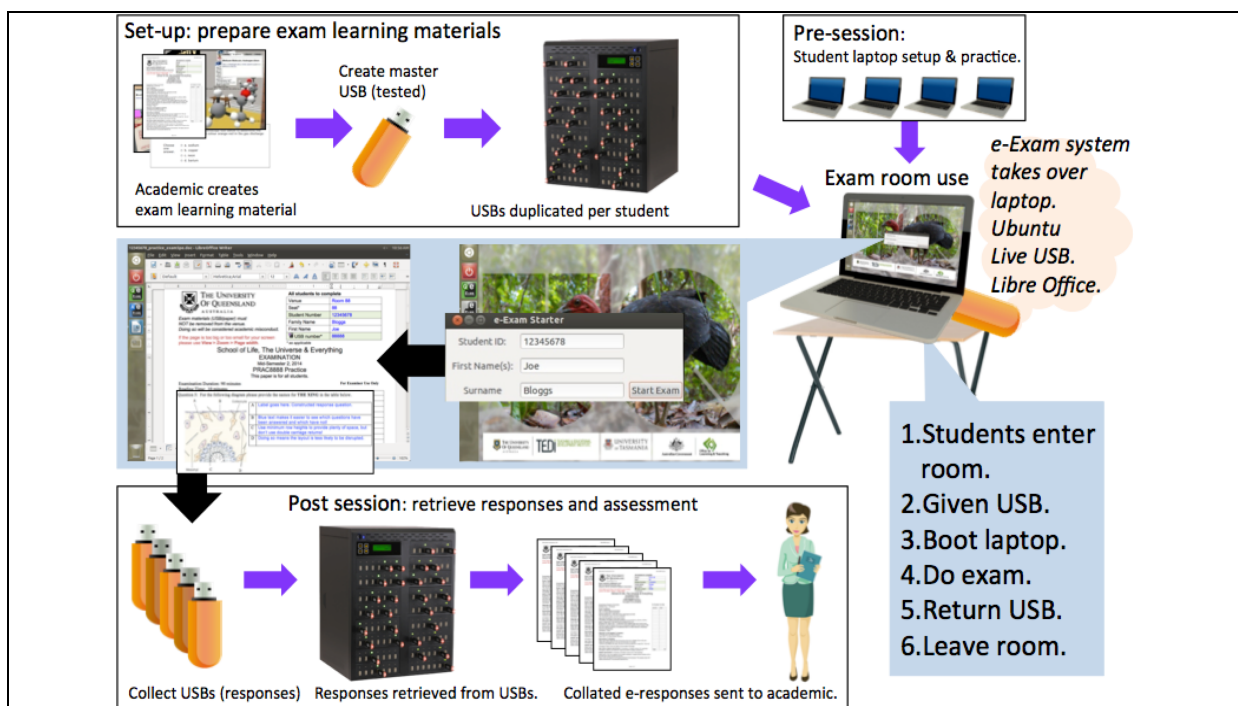

Figure 4: e-Exam Trial workflow.

Study Method

The first step for student involvement in the exam trials was for students to complete an online 'expression of interest' (and consent form) indicating their choice of exam mode. Students were advised that they could change their mind at any time. The default for a non-response was handwriting. Those who expressed interest in typing were then asked to attend a set-up / practice session to provide an opportunity to become familiar with the e-Exam system and to ensure that the e-Exam system was compatible with their laptop. Those that attended the session were asked to complete a survey to collect data about their laptop and their first impressions of the e-Exam system. Finally, all students (both typists and hand-writers) undertook the exam and were asked to complete a post-exam survey.

The two surveys used in the exam trial included a number of selected-response and several open text questions that provided an opportunity for students to report their impression and experience of the e-Exam trial. The focus in this paper is on reporting the outcomes of the selected-response questions while the emergent themes from the open response questions are reported elsewhere in Hillier (2015). Note that the responses from the selected-response items in the pre-project survey (phase 1) are reported in Hillier (2014).

E-Exam Trial Participation

The participant numbers at each step of the trial were monitored with the expectation that there would be attrition given the voluntary nature of the study. The number of students at each stage is displayed in Table 1.

Table 1: Number of typists at each stage of the e-exam trial

Steps of trial	Yes will type	Maybe type	Total typists	Attrition	No (hand-write)*
1 Expression of Interest	201		201		361
2.1 Pre - before try	94	16	110	91	10
2.2 Pre - after try	86	15	101	9	23
4 Exam (after)	71		71	30	450
Note: not all respondents completed every question. A number of students electing to hand-write did not fill in the expression of interest and the post-exam survey so are slightly under represented. Similarly not all attendees at the pre-exam set-up session returned a survey.					

There were just over 200 students (36%) out of approximately 560 students in the six courses who expressed interest in typing. Of these, 124 attended a set-up/practice session with 115 surveys returned. During the set-up/practice session, 94 said they intended on typing the exam before they had tried the e-Exam system. After trying the e-Exam system with their laptops, 86 said they still intended on typing their exam. Several students were offered the chance to book a university owned laptop due to their own being unsuitable. On exam day, 71 students typed their exam and 450 defaulted to hand-writing their exam.

Participation for each of the six courses ranged from 5% to 34% with an overall 16% of students electing to type. The mid-semester exams ranged in duration and structure from 15 minutes of writing prior a practical clinical exam to 100 minutes of writing that involved short answer, essay and selected-response items. All e-Exams utilised word processing documents to facilitate typing. However, some exams used optical mark recognition sheets to collect larger groups' multiple choice question responses. In cases where there were only a couple of selected response items in an exam, these were included in the word processor document with a response recorded by typing an 'x' into an appropriate box. The details of each course exam and the participation counts are listed in Table 2.

Table 2 Number of typists in each course e-exam trial

Course and Exam Type	Typed	Handwrote
Animal Biology: 45 min mixed short answer and MCQ (type 'x')	5	109
Zoology (BIOL): 50 min short answer (MCQ section done pen on OMR sheet)	10	81
Criminology: 70 minutes. Single long essay response section (MCQ section done pen on OMR sheet)	17	50
Occupational Therapy: 100 min mixed short answer and MCQ (type 'x')	3	24
Physiotherapy: 15 min (watch video and write into a table) before clinical exam	25	108
Veterinary technology: 90 min theory, mostly short answer	11	78
Totals	71	450

Findings

Analysis of selected-response items, in particular Likert scales followed advice from Dermo (2009). The Likert scale data were considered to be non-parametric (Jamieson, 2004) and so Mann & Whitney's (1947) U test on the variance of two groups and Kruskal & Wallace's (1952) test in instances of more than two groups were used in SPSS v22. The results of the pre and post exam phases of the data collection are presented in the following sections. Like Dermo (2009) we are interpreting statistical results as an indication of the body of opinion from students rather than a search for a single truth. Means are also given where applicable to assist the reader in understanding responses to five point scales.

Pre-exam First Impressions

During the set-up/practice session, student's initial impressions and intentions were surveyed prior to tying the e-exam system with their laptop and immediately following their first try of the e-exam system. Students were asked to rate the e-exam system using Likert items including the ease of following set-up instructions, the ease of undertaking the start-up steps, the ease of starting their computer with the USB stick and the ease of using the exam system software. They were also asked about their confidence in their ability to perform the necessary steps in a real exam and if they were 'relaxed' about the idea of using the e-exam system in their upcoming exam. These questions comprised the five point Likert items listed in Table 3, with 5 being 'strongly agree'.

Table 3. Selected pre-exam session survey questions (typists only)

Question	N	Mean	SD
The written instructions were easy to follow.	108	3.9	1.0
It was easy to learn the necessary technical steps.	105	4.0	1.1
It was easy to start my computer using the e-Exam USB.	108	4.1	1.2
I feel confident I will be able to do these steps in a real exam.	106	4.0	1.1
The software within the e-Exam system was easy to use.	105	4.1	1.1
I now feel relaxed about the idea of using the e-Exam system for my upcoming exam.	106	3.8	1.0

At the end of the session, 115 surveys were returned. A graphical representation of the spread of responses on each item is displayed in Figure 5. Most were rated as 4 on the 5 point scale (5 being strongly agree/positive).
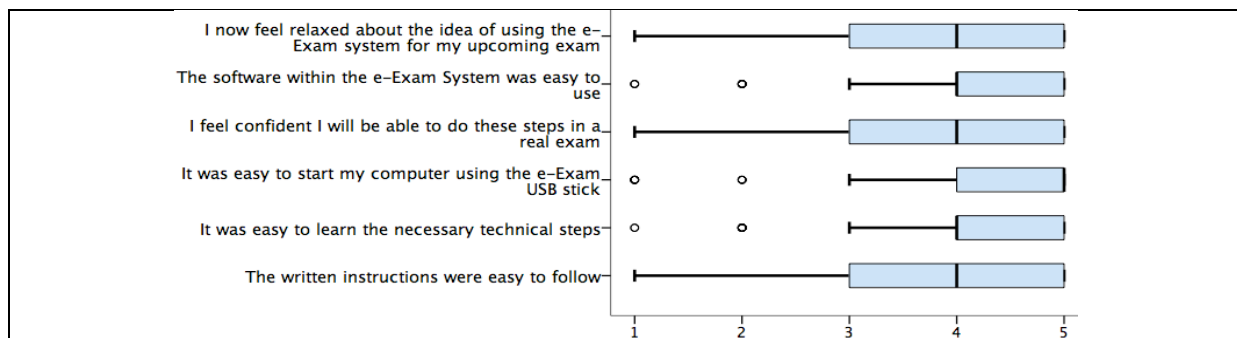

Figure 5: Ratings of the BYOD based e-exam system (5 = strongly agree)

Technical information was also collected relating to each student's laptop. This included brand/make, model/serial number, operating system used, estimated battery life, any technical adjustments required (e.g. secure boot settings and BIOS/EFI mode) and compatibility with the e-exam system including boot, graphics and performance of touch pads.

A wide range of equipment was presented for testing with the single most common brand and operating system being Apple OSX with close to 70% of machines. The remainder of computers utilised versions of Microsoft windows 8 and 7 on nine different brands of hardware. The results of technical testing of student's laptops showed that around 20% were found to be incompatible with the e-exam system due to graphics card or other indeterminate issues related to EFI or BIOS limitations. A planned upgrade to the e-Exam operating system is expected to reduce this issue in the future. Students were offered the opportunity to reserve a backup laptop in the event theirs was not suitable. Several non-critical issues were identified that lead to contingencies being put in place, such as provision of power or additional instructions to adjust screen resolutions where retina screens were used. Figure 6 provides numerical details of student hardware and test results.
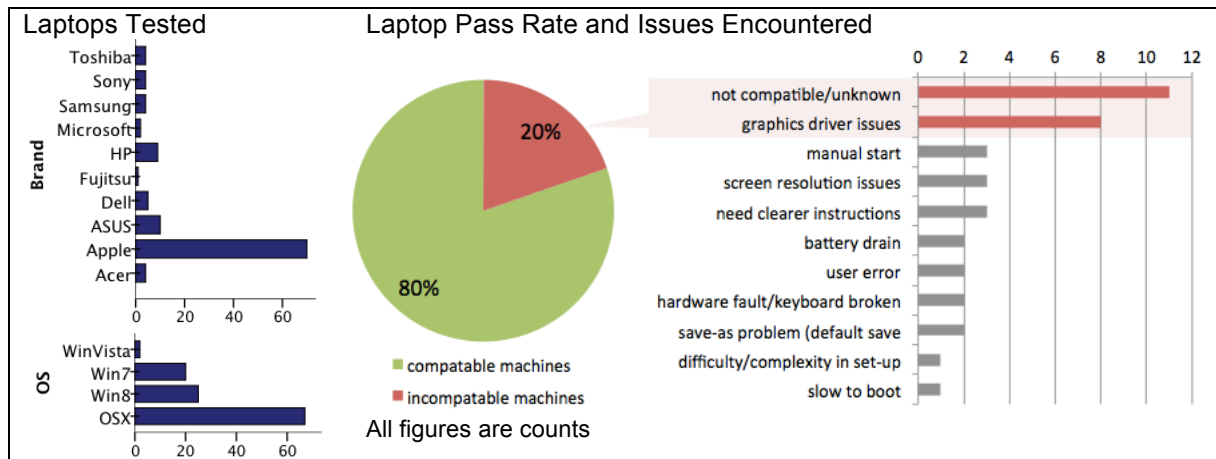
Figure 6: Laptop testing results

Post-exam Findings

The post-exam survey was conducted following the collection of exam responses. The survey contained a number of selected response items covering students experience of the exam session, stress or comfort levels, adequacy of exam timing, ease of use of the exam system, suitability of the exam questions for computerisation, writing strategies and general use of computers for study related writing tasks.

Table 4. Selected post-exam session survey questions

Question	Typists			Hand-writers		
	N	Mean	SD	N	Mean	SD
I typed (or handwrote) this exam.	71	-	-	450	-	-
I felt the e-exam system was easy to use.	69	4.4	0.8	-	-	-
I felt the e-exam system was reliable against technical failures.	69	4.1	1.0	-	-	-
I felt the e-exam system was secure against cheating.	69	4.3	0.9	-	-	-
I liked the fact I could use my own computer.	61	4.5	0.8	-	-	-
I would recommend the e-exam system to others.	68	4.3	0.9	-	-	-
Overall my experience of this exam was positive.	71	4.0	1.0	439	3.8	1.0
I ran out of time.	70	2.6	1.5	437	2.6	1.5
I felt more stressed in this exam than I normally do in other exams.	70	2.6	1.3	439	2.7	1.3
I went back over my responses before submitting.	71	3.5	1.5	439	3.5	1.4
I would like to use a computer for exams in the future.	13	4.2	0.9	99	1.8	1.0
I felt this particular exam suited the use of computers.	70	4.2	0.9	-	-	-
I think my handwriting was neat and legible.	-	-	-	453	3.4	1.2
I experienced discomfort in my writing hand.	-	-	-	389	2.4	1.3
I type faster than I handwrite.	67	4.5	0.9	368	3.7	1.5
I type accurately.	66	4.2	1.0	369	3.5	1.1
When I make errors, I can quickly correct them as part of typing.	67	4.5	0.8	368	3.9	1.1
I often rely on spell check to detect errors.	67	3.4	1.3	368	3.6	1.3
I work more efficiently when I type on a familiar keyboard.	67	4.5	0.9	368	4.3	0.9
My hand-writing is normally neat and legible.	67	3.3	1.4	368	3.5	1.1

Questions relating to student's impressions of using the e-Exam system are shown in Figure 7. The feedback was generally positive with ratings of 4 or above on a 5 point scale across multiple items.
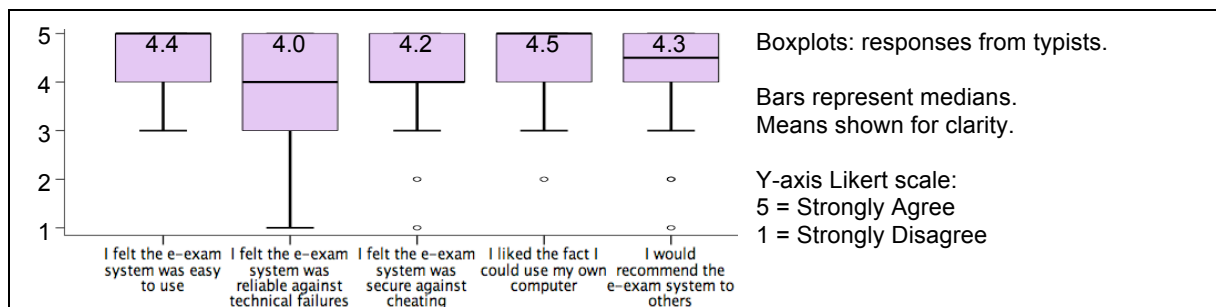

Figure 7: Student impressions of using the exam system

Those that typed were also asked if they felt the exam they had just done suited the use of computers. The majority of students agreed or strongly agreed with the statement with a mean of 4.2 (see Figure 8). It is worth noting two issues at play here. First, students who typed are self-selecting and are thus predisposed to agreement. However, the exams were designed such that paper or computer could be used and therefore elements such as multimedia or interactive tools that would have added value were not possible in these exams making the 'value add' of computerisation much more limited.
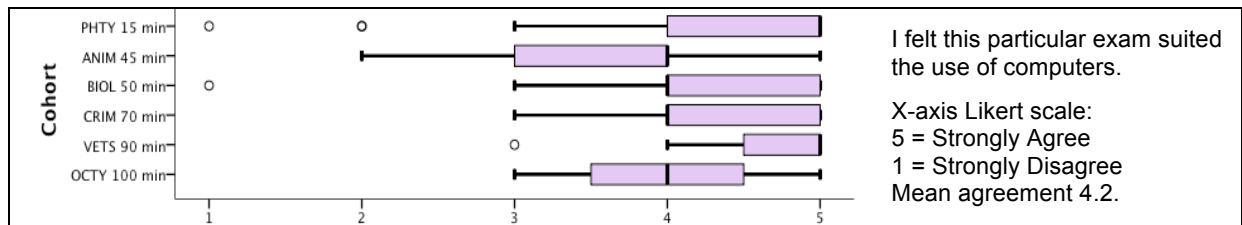

Figure 8: Student reported suitability of each exam for computerisation.

All students were then asked about their direct experience of the exam session conditions. An aggregated analysis across the six courses was performed to compare responses from typists and hand-writers on questions that related to their overall experience of the session, time availability, stress and whether they re-checked their responses prior to submission of responses. Students were also asked if they would consider using a computer in a future exam. Results are graphically presented in Figure 9 and Mann-Whitney U test results in Table 5 that shows the only significant difference in their 'overall experience'. Visual inspection also reveals that typists were slightly less stressed than hand-writers. A question relating to future intended use of computers for an exam was introduced for the final two courses. The differences by exam mode were significant and while this was expected given the self-selected nature of the two groups, there were some hand-writers who had interest in using a computer for exams in the future.
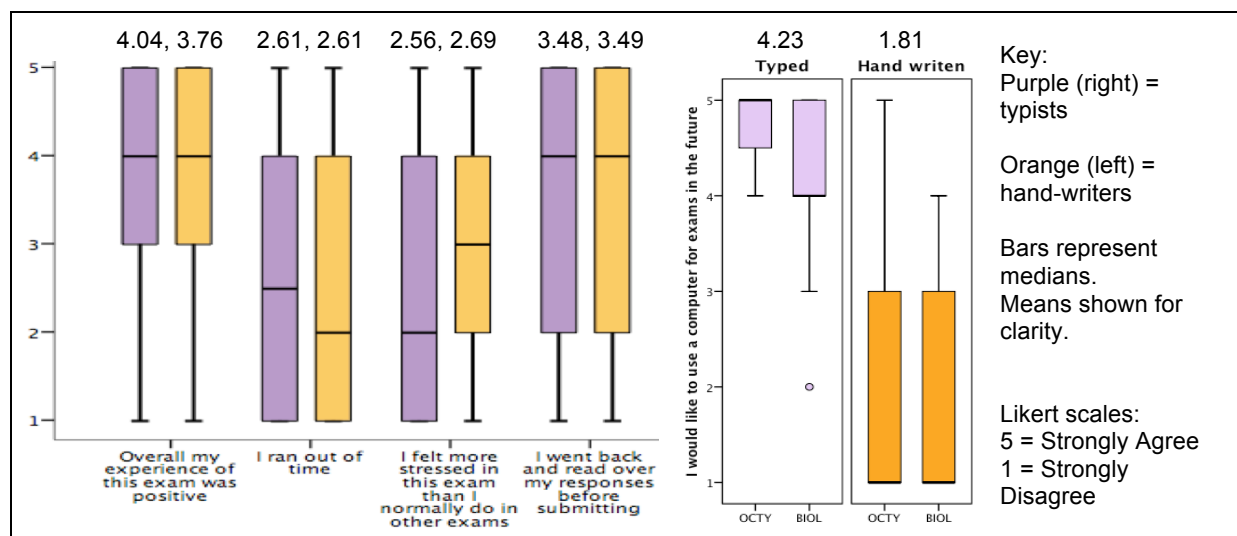

Figure 9: Student reported experience of exam conditions and future intentions.

Table 5: Test Statistics for Student reported experience of exam conditions and future intentions

Grouping Variable: I typed this exam (Yes / No)	Overall my experience of this exam was positive	I ran out of time	I felt more stressed in this exam than I normally do in other exams	I went back and read over my responses before submitting	I would like to use a computer for exams in the future
Mann-Whitney U	13242.5	15203	14527.5	15145.5	74
Z	-2.132	-.083	-.751	-.394	-5.532
Asymp. Sig. (2-tailed)	>.05	n/s	n/s	n/s	>.001

Issues identified by students in their post session comments (Hillier, 2015) and in the phase 1 survey (Hillier, 2014) indicated that the neatness of handwriting and discomfort such as cramps experienced in longer exams was a recognised issue. Anecdotal comments from teachers involved in the trial also indicated a perceived decrease in the readability of student's handwriting in exams. To explore these two issues, hand-writers were asked if they thought their handwriting was neat (N 453) and if they had experienced any discomfort in their

writing hand (N 389). Figure 10 displays the responses of students on these two issues by course exam. There were moderate levels of self-reported agreement (mean 3.4) in respect to the neatness of handwriting under exam conditions that was reasonably consistent across the different courses. This would appear to contradict the anecdotal reports from teachers. Significant differences >.001 were reported from a Kruskal-Wallis Test in the level of discomfort experienced when taking into consideration the length of the exam. The 70 minute mark was the transition point where a majority of students felt discomfort. Exams shorter than 70 minutes did not present undue issues for hand-writers although a minority were reporting discomfort in the 45 and 50 minute exams. In the longer exams of 90 and 100 minutes, while higher levels of discomfort were reported had a mixed response rate (VETS 18%, CRIM 73% and OCTY 92%) and lower numbers indicate that results still need to be interpreted with some caution.
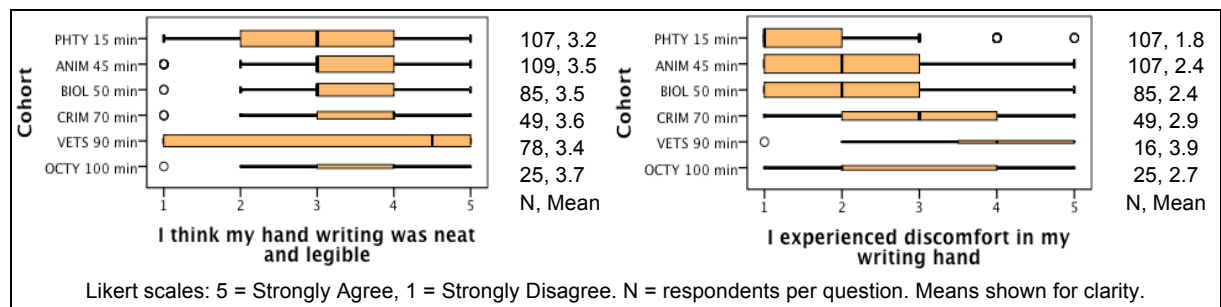

Figure 10: Student reported neatness of handwriting and discomfort by exam duration

Students reported in the phase 1 survey (Hillier, 2014) that their typing ability was likely to play a big part in them choosing a computerised exam. We asked trial participants to report on their abilities with respect to typing in general (outside of the exam context) including speed, accuracy, error recovery, spelling and error detection. They were also asked if they felt they were more efficient on a familiar keyboard given a strong response exhibited in the phase 1 survey in relation to using familiar keyboards. We also asked if they felt their handwriting was neat and legible in general. Results comparing those who elected to type the exam with those that hand-wrote are shown in Figure 11 as Boxplots with means also shown for clarity.
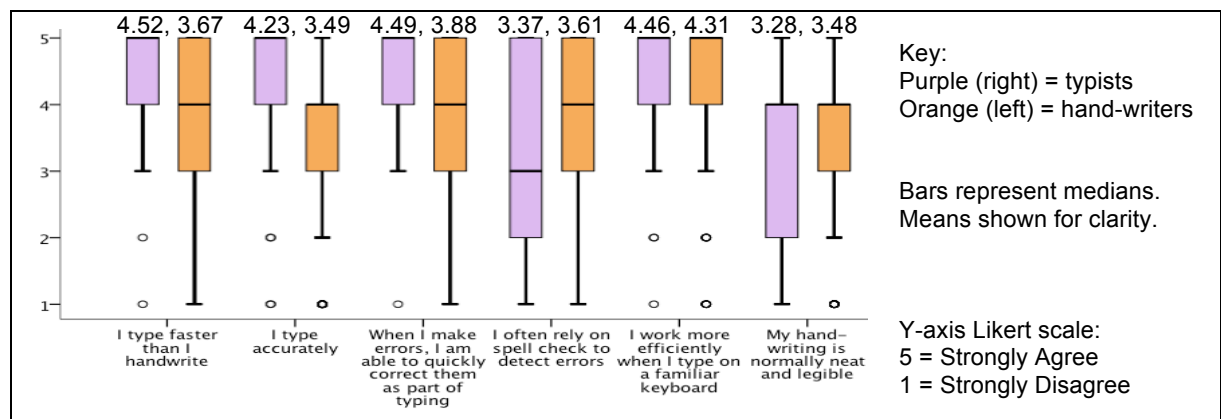

Figure 11: Student reported use of typing and writing in general

Significant differences were in favour of typists on matters of perceived typing speed, typing accuracy and being able to quickly correct errors when typing. However the degree of reliance on spell check, perceptions of efficiency on a familiar keyboard and self-reported general neatness of handwriting did not appear to be major factors in choosing to type the exam. These results are displayed in Table 6.

Table 6: Test Statistics for student reported typing and writing in general

Grouping Variable: I typed this exam (Yes / No)	I type faster than I handwrite	I type accurately	When I make errors, I… quickly correct them as part of typing	I often rely on spell check to detect errors	I work more efficiently when I type on a familiar keyboard	My hand-writing is normally neat and legible
Mann-Whitney U	8213	7551.5	8523	11097	10917.5	11621.5
Z	-4.637	-5.089	-4.248	-1.342	-1.656	-.770
Asymp. Sig. (2-tailed)	>.001	>.001	>.001	n/s	n/s	n/s

Conclusion

The above results, in conjunction with findings published elsewhere (Hillier, 2014; 2015) raise awareness of relevant issues for institutions setting out to trial and implement computerised examinations. This paper looked at a range of student self reported impressions of their experience in undertaking a trial e-Exam in their course via 'selected-response' questions to pre and post exam surveys. Students were provided a choice as to typing or handwriting and so we were able to compare responses from these two groups. Self- reported speed of typing over handwriting, typing accuracy and an ability to correct errors when typing were found to be significant factors in students' choice of exam mode.

Students who chose to type reported positively on their experience with the e-Exam system, giving ratings of 4 or above on a 5 point scale. Similarly, typists' impressions of the experience were positive overall and were slightly less stressed than those that handwrote. Findings show that those that hand-wrote their exam experienced discomfort in their writing hand as the duration of the exam increased. It was found that the 70 minute mark was the point at which the majority of students were impacted. However, some students were still impacted during 45 and 50 minute exams.

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