Landscape Report: Research and Practice in E-exams

Dr Liz Masterman
Dr Jill Fresen
Academic IT

Document history

Date	Version	Notes
1st September 2017	1.0	First publication: for distribution to members of the University of Oxford only

Acknowledgements

TABLE OF CONTENTS

1. INTRODUCTION

1.1 E-EXAMS AS A METHOD OF DIGITAL ASSESSMENT IN HIGHER EDUCATION

Digital assessment — the use of computer technology in the preparation and administration of assessment activities — is now of strategic importance in higher education, according to recent reports by the Gartner Group.[1]

Digital technologies are perceived to open up possibilities for transformation in assessment scenarios and question types (Hillier, 2013; Jisc, 2010; Timmis, Broadfoot, Sutherland & Oldfield, 2016). Within the higher education sector, interest in digital assessment has mainly focused on tools for handling online exams, computer marking, authentication and security, objective assessment in a digital medium and the invigilation of online exams held at a distance. Less attention has been paid to e-exams: timed examinations in which students type their responses on a computer in the physical presence of an invigilator (typically, in an exam hall or other room allocated for the purpose). Indeed, in some overviews of the digital assessment field, e-exams are either disregarded altogether or receive only a passing mention (e.g. Jordan, 2013; Jisc, 2007).

Even so, e-exams have been standard practice in US law schools for a number of years (Augustine-Adams, Hendrix and Rasband, 2001; Mogey, Paterson, Burk & Purcell, 2010). They are becoming commonplace in Scandinavian countries, where Sindre and Vegendla (2015a) forecast a large-scale shift towards e-exams during the coming decade. Further along in the examinations process, on-screen marking (albeit of scanned handwritten scripts) is now standard practice for most major public examinations in the schools sector in China and Hong Kong (Coniam & Yan, 2016).

The perceived benefits of e-exams, which are explored in detail later in this report, include:

- familiarity with the digital medium (typing is now the norm in essay writing);
- greater physical comfort (compared with handwriting for extended periods);
- possibility of incorporating multimedia elements into questions; and
- streamlined management of assessment.

(Hillier, 2013; Sindre & Vegendla, 2015a)

1.2 ORIGIN AND OBJECTIVES OF THE E-EXAMS PROJECT

Within the University of Oxford, objective assessments have been conducted in a digital medium for at least a decade, notably in the Medical Sciences Division (formative and summative) and the Department of Continuing Education (formative only) (see Appendix A). However, an interest in e-exams is becoming discernible among departments and faculties. In 2014, the History of Art Department, in conjunction with researchers from the Department of Education, proposed a project to investigate the benefits of e-exams from the perspectives of the students and academics involved. However, the project was not carried out.

In the consultation survey that followed the publication of the University's Digital Education Strategy (2016), respondents expressed interest in the online submission of summative work (e.g. term papers and dissertations), but not in e-exams *per se*. However, when the Social Sciences and MPLS divisions subsequently prioritised their digital education needs, they included e-exams. Indeed, the

---

[1] http://prwire.com.au/pr/50060/gartner-highlights-the-top-10-strategic-technologies-impacting-education-in-2015, https://www.gartner.com/doc/3186323/top--strategic-technologies-impacting, https://www.gartner.com/doc/3557217.

commentary on the feedback to the consultation identified the following priority: 'There is interest across a number of divisions to implement computerised exams in a number of formats (e.g. writing exam scripts on computers, bring your own device, computer marking etc.).' The authors went on to comment: 'A greater understanding of the resources and technologies required is needed to be able to support departments in their decision making and implementations' (quoted in the E-exams Project Brief).

The E-exams project was set up in order to achieve this greater understanding. In collaboration with Medical Sciences and a number of interested departments in the other academic divisions, IT Services is investigating the potential for e-exams, and will fund and run trials during the 2017-18 academic year.

In summary, the E-exams project objectives are to:

- survey the wider landscape to understand the software and processes in use by other institutions, the resources required to run examinations on computers, and the benefits derived for both students and academics;

- support trials during the 2017–18 academic year with departments and faculties that have expressed interest in e-exams;

- from both the landscape report and the outcomes of the trials:

    - assess the impact of any move towards typing exams: the resources required, and the experience of students and academics in (respectively) sitting and marking the exams;

    - identify benefits and challenges, and enable the Academic IT group to provide guidance for departments and colleges that are considering implementing e-exams; and

    - document the potential approval process if e-exams are to be allowed beyond the trials that will take place under the scope of the E-exams project.

This report supports the first of the project objectives.

1.3 APPROACH

To arrive at a description of the current e-exams 'landscape' in both the UK and elsewhere, we surveyed:

- peer-reviewed research into the psychological and academic aspects of changing from handwritten to typed exams; and

- reports of previous trials and current practice in other institutions in order to extract best practice in relation to practical aspects, process and policy.

The materials were gathered primarily from a search of online materials using Google Scholar. They also include documents collected as a result of exploratory meetings with other institutions earlier in 2017.

The Google Scholar search was conducted intensively over a period of two days in late June 2017; terms used to locate documents include (in alphabetic order):

- computer + essay + exams
- computer anxiety
- computer-based exams
- computerised exams
- digital assessments
- digital examinations
- essay exams

- online exams
- typed exams

The works collected comprise:

- peer-reviewed journal articles and full-length conference papers;
- 'grey' (i.e. not peer-reviewed) literature: reports of projects, evaluations and surveys; also overviews of the field;
- pages from university websites providing guidance on e-exams to staff and students; and
- blog posts.

We aimed to restrict our search to works published from 2000 onwards. This was for two reasons. First, developments in technology meant that papers from the 1980s and 1990s described software with outdated functionality. Second, authors of some research articles often included pre-2000 studies in their literature surveys, and so we felt it unnecessary to read the cited works as well. We made exceptions to the cut-off date where the findings of pre-2000 studies proved to be particularly relevant to the E-exams project and we wanted to cite them individually in the report.

Additional works of interest were located in the references of articles found through the Google Scholar search, and also on journal websites which listed related items alongside the article being read.

We logged a total of 79 works of the types listed above in a shared spreadsheet. We then categorised the works thematically according to the areas of interest identified in the E-exams project objectives, and divided the detailed reading and analysis between us. One author worked on papers relating to the psychological and academic aspects of e-exams, and the other worked on materials relating to practical and policy considerations. We discarded 24 items during the detailed reading, either because they proved irrelevant on closer scrutiny, or because they reported findings that were repeated or superseded in later publications from the same research study. The References section lists the 55 works from which we have included findings or other information in this report.

We also included in our survey personal communications with colleagues in Oxford and email correspondence with individuals from other institutions. A number of these individuals responded to requests for information that we sent to mailing lists of the Association for Learning Technology and the ARC Assessment Practitioners' Group.

From the research studies and trials reviewed, we additionally identified different methods and instruments for evaluating the impact of e-exams on students and staff. These are summarised in Appendix B.

2. THE CURRENT STATUS OF E-EXAMS

2.1 E-EXAMS IN THE UK: THE BROAD PICTURE

Although there have been isolated trials of e-exams in the UK since at least 2008 (e.g. Mogey et al., 2010; UCL, 2011), e-exam technologies did not feature in UCISA's biennial Survey of Technology Enhanced Learning until 2016 (Walker et al., 2016). Overall, the 2016 survey received responses from 110 out of a possible 160 universities, and so the data can be considered a reasonably sound indication of trends. A question asking about centrally supported tools for TEL in general received 105 responses, only 14% of which stated that they used electronic essay exam tools (the term used in the survey for e-exam tools). This compares with 85% for other types of assessment tool used in summative e-assessments and 91% for other types of assessment tool used in formative e-assessments. The e-exam tools cited were the institutional VLE (10, mainly Blackboard), Turnitin (4) and commercially available dedicated exam tools (2, not named). Within institutions that provide e-exam tools, take-up appears to be low: only one institution stated that it uses e-exams across all courses.

The fragmentary implementation of e-exams within institutions may be explained in part by data from a survey conducted by the Heads of e-Learning Forum (HeLF) (Newland & Martin, 2016). According to responses to a question about the replacement of traditional summative exams with online exams, current initiatives are largely at the course or departmental level only (73.5% of 49 respondents). Since the survey questions addressed a range of formative and summative assessment methods without differentiation between them, it is not possible to single out data on e-exams specifically. Even so, the survey data indicate a growing appetite nationwide for online exams of all kinds. Two-thirds of responding institutions reported that they have an institutional policy for online submissions, even if not for other aspects of the process (e.g. marking, feedback and the return of scripts).

The HeLF survey data also indicate a strong interdependence between different stakeholder groups at different levels of the institution. Although online exams are 'owned' by the central exams office, their implementation depends on local TEL teams, the student systems team, IT services and student services.

2.2 EXAMPLES

Table 2.1 overleaf lists 10 universities in the UK and Europe that have trialled or implemented e-exams. Further details on each of these implementations are provided in Appendix A.

Table 2.1. E-exams: examples at other universities. BYOD = 'Bring your own device': i.e. students take exams on their laptops (see section 4.2.1).

Country	Institution	Status *Technology used*	Software	Key points of interest
UK	Brunel	Two pilots running high-stakes digital examinations (2015/16 and 2016/16) Staged roll-out across the institution from Sept 2017 *BYOD*	WISEflow	Students are offered a choice to use own devices — those who decline are offered a loan device, or space in a PC lab. Wi-Fi masts have been installed to boost connectivity. Near-military precision enabled them to successfully deliver 18 digital examinations during May 2017. Student numbers ranged from 17-218, and a total of ~1600 electronic submissions were made.
UK	Cambridge	Piloted 3 exams in April 2017 *BYOD*	DigiExam	Cambridge University ran a small 'proof of concept' project in April 2017, with two departments: Classics and History. It was strictly opt-in with students being offered the choice to change from typing to handwriting, even during the exam. Careful attention was paid to all aspects of planning including backup plans, student communication and student training.
UK	UCL	Trialled in 2011 with very small student numbers in one faculty *BYOD*	Exam4: considered to be immature; not recommended	The pilot highlighted some issues and challenges, in particular the lack of student engagement and heavy staff resource requirements. The small-scale pilot took approx. 300 hours of staff time (admin staff and technical support). Given the lack of take-up, and the remaining issues and questions, they did not move beyond a pilot to Phase 2.
UK	Edinburgh	Small trial in School of Divinity in 2006 Implemented 2012-2016 Retired the service in 2016 Planning to review in 2018 *BYOD*	Exam4: considered to be limited in what it could do; since discontinued Currently considering ExamOnline, WISEflow	Students were offered a choice between typing or handwriting in an essay exam. The team's research focuses on student choices and performance comparing these two options. Loan machines were available, if needed. Exam questions were handed out on paper to all candidates; handwritten scripts were collected in the traditional manner. Marking was done on paper.
UK	LSE	Law pilot study in 2014-2015 (two modules) *BYOD*	ExamSoft	Both pilots were timed, take-home formative mock exams. The aim was to explore students' perceptions of typing versus handwriting exams and to consider the impact on academic and support staff who were involved in the process.

Country	Institution	Status *Technology used*	Software	Key points of interest
UK	Open University	Small pilots during 2013 to 2015 academic years *BYOD in normal exam halls*	Moodle with secure exam browser (SEB)	Input was text only. Each student was provided with a hard copy of the question paper for reference and an answer book for rough working. The team encountered technical issues in both OU and non-OU centres, mostly to do with Wi-Fi issues. Invigilators were present throughout. There were no recorded instances of student cheating/hacking or attempting to do either. They report numerous blockers to adoption at scale, mostly university infrastructure-based.
UK	Edinburgh Business School (Heriot-Watt)	Implemented in 2016 — gradual rollout across the school *Looking at BYOD in the future*	BTL Surpass	The school offers a global distance learning MBA, with e-assessment offered in exam centres worldwide, in a secure, locked-down and invigilated environment. At the beginning of June 2017, they delivered exams in 68 exam centres, for 12 different subjects. The pen-and-paper option is offered as an exception.
UK	Dundee	Pilot in 2011-12 with one department — Life Sciences Now implementing *University desktop computers*	ExamOnline — developed by Scottish company Intelligent Assessment Technologies	ExamOnline (EO) consists of three apps: authoring, delivery and results. It allows the input of hand-drawn diagrams to support an answer. Used at Dundee only for summative essay/short answer question typed taken in an invigilated IT room, on institutional desktop PCs. Anonymous on-screen marking is enabled, as well as export to PDF for marking offline. They have not investigated BYOD, but may do so in the near future.
Norway	Bergen	Implemented in Faculty of Mathematics and Natural Sciences *Unknown whether BYOD or university computers*	Inspera — apparently 'still under development' — at the time there were 'many bugs and cumbersome solutions for task creation' (Univ of Bergen, 2016, p. 24)	Two major barriers of Inspera (in 2016) were that it did not enable students to write mathematical or chemical formulae, or to draw diagrams (the latter functionality has since been enabled). Although the system supports syntax for over 50 programming languages, it was not possible to compile or run computer code. The system can be used for formative assessment in the form of term papers and take-home exams.
Denmark	Aarhus University School of Business and Social Sciences (BSS)	Implemented at beginning of 2014 *BYOD*	WISEflow (which was developed at Aarhus University)	They chose a 'big bang' implementation strategy by digitising all written exams in the 2014 summer exam period. It is used across 7 departments, with a total of 14,000 students. WISEflow enables workflows for all aspects of a written exam — set-up, delivery, assessment, and archiving.

3. TYPED *VS* HANDWRITTEN EXAMS: INTELLECTUAL PROCESSES AND ACADEMIC OUTCOMES

3.1 A QUESTION OF EQUIVALENCE

In surveying peer-reviewed research into the psychological and academic aspects of changing from handwritten to typed exams, we aimed to uncover findings that might inform decisions relating to the practical, procedural and policy aspects of implementing e-exams.

The question underpinning this section of the report is 'are handwritten and typed exams equivalent?' It can be divided into three parts:

1. For students sitting e-exams:

   Does moving from handwritten to typed exams change the intellectual process of responding to an exam question and, hence, the length and stylistic features of the resulting response?

2. For markers of e-exams:

   2.1 Does moving from marking handwritten exam scripts to typed scripts change the marker's perception of, and attitude towards, students' responses?

   2.2 Does moving from marking exam scripts on paper to marking scripts online change the intellectual process of marking an exam question?

3. If the move results in change, is there a difference in the marks achieved/awarded, and should the differences be considered important?

3.2 TYPING *VS* HANDWRITING EXAM RESPONSES

3.2.1 AN OVERVIEW OF THE WRITING PROCESS

In order to appreciate the potential differences between handwriting and typing exam responses, an overview of the fundamental metacognitive processes involved in text composition may be helpful. Peverly's (2006) survey of models of writing competence provides a basic understanding of these processes. Under exam conditions, the processes are:

- planning (goal setting, generating and organising content),
- retrieving knowledge,
- translating (turning ideas into text) and
- revising the text produced so far.

Translating one's ideas into text on the paper or screen entails two further processes: text generation and transcription. Text generation involves 'translating generated ideas into language in working memory and then translating those temporary mental representations into more permanent external representations using the symbols of the writing system.' Transcription involves 'retrieving letter forms and familiar word spellings from long-term memory, strategically spelling novel words, and motor planning to produce the letters [using the tool at hand]' (Peverly, 2006, pp. 199–200).

An individual's capacity to carry out these high-level processes depends in part on the efficiency, or fluency, of the lower-level processes involved in outputting the text onto paper or screen. Summarising a number of models, Peverly suggests that:

> Writers must (a) be fluent in generating ideas that can be written down and (b) write these ideas down quickly before they are forgotten. If writers are efficient in executing (a) and (b), they will be able to use the metacognitive processes … and other cognitive

resources (e.g., genre and content knowledge…) to create reader-based prose (2006, p. 199).

The pressurised environment of an exam may place additional pressure on the capacity of a student's metacognitive processes, with a resultant impact on the quality of their responses (Connelly, Dockrell & Barnett, 2005).

3.2.2 INTELLECTUAL PROCESS AND PRODUCT

Insights into differences between handwriting and typing in the intellectual processes of writing an exam response[2] are derived largely from students' self-reports. Hand-writers in Lee's (2002) study reported that they spent more time planning their responses before starting to write than the typists did.[3] Typists reported that they composed their responses in a rough form first, then went back and expanded them; they also paused more while they were actually writing (i.e. they may have needed more time to think while producing the text because they had spent less time planning).

However, studies are inconsistent, or even contradictory regarding the differences (Lee, 2002). For example, participants in Kohler's (2015) study stated that they re-read and revised their writing more while typing than handwriting. This finding stands in contrast with the finding by Hillier (2015b), in whose study similar proportions of hand-writers and typists reported that they went back over their responses before submitting. The exact nature of differences in the processes may differ from student to student (Lee 2004); furthermore, these differences may be insignificant from a methodological perspective (Mogey & Paterson, 2013).

Differences between typing and handwriting are more clearly discernible in the finished product. The salient difference is in length, with typists generally producing longer responses than hand-writers in several studies (Charman, 2014; Kohler, 2015; Lee, 2002; Mogey et al., 2010; Whithaus, Scott & Midyette, 2008). However, it is important to note that the length of a student's exam response depends on their content knowledge and analytical skills as well as on their typing or writing speed (Augustine-Adams et al., 2001).

Discrepancies exist in the findings of research into the length and organisation of sentences in students' responses. Mogey and Hartley (2012) found that typists produce more, but shorter, sentences and arrange them into a smaller number of paragraphs; Kohler (2015) also observed that typists write fewer (i.e. longer) paragraphs than their handwriting peers. In contrast, Lee (2002), and Mogey and Paterson (2013) found that typists produce longer sentences.

Research into the linguistic features of typed and handwritten responses reveals further differences. Charman's (2014) detailed analysis of responses produced by A Level students revealed greater lexical variation in typed responses, but a slightly greater lexical density in handwritten responses.[4] Mogey and Hartley (2013) also observed greater lexical density in students' handwritten responses. Both measures — variation and density — tend to be higher in writing than in speech. These findings led Charman, and Mogey and Hartley, to suggest that students may write in a more informal style on the computer than on paper. Indeed, Mogey and Hartley report that one participant in their study commented that technology had led him to write more informally and that he found it difficult to switch to academic writing. Once again, the findings are not consistent across studies: for example, Whithaus et al. (2008) found that handwritten exams were in a more informal style than typed ones.

---

[2] Most of the studies surveyed for this report refer to the assignments that students were required to complete as 'essays' or 'tests', since few were actually carried out in actual examination settings. However, for convenience and to keep the focus on the subject of the current project, all such assignments are referred to as 'exams'.

[3] For conciseness, 'hand-writers' and 'typists' are used in this report to denote, respectively, students who write their exam responses by hand and students who type their responses on the computer.

[4] Lexical variation is a measure of the range of vocabulary employed and the amount of repetition; lexical density is a measure of the proportion of meaning-bearing words to functional words (greater density indicates a greater proportion of meaning-bearing words).

3.2.3 INFLUENCE OF THE TOOL

The speed of the motor act of transcription — whether handwriting or typing — can determine how much of a student's working memory is available for the higher-level actions involved in text composition (Peverly, 2006). Indeed, combined with exam pressure, speed can have an impact on a student's exam performance, as Connelly et al. (2005) point out in relation to handwritten exams:

> … it is only when cognitive load is high that handwriting fluency becomes an important predictor of writing quality. This does not bode well for handwritten exams, where it is presumed that the quality of knowledge produced reflects the learning of the student, not simply how fluently they can write (p. 106).

In view of research suggesting extensive computer use can impair fine motor skills including handwriting (Sülzenbrück, Hegele, Rinkenauer & Heuer, 2011), the argument in favour a move to e-exams would appear strong. It is further reinforced by the expectation that much coursework is typed; as a result, students may have little or no practice writing essays by hand (Mogey et al., 2008).[5]

Although it has been observed that students generally type faster than they can handwrite (Augustine-Adams et al., 2001) and that they may complete their exams more quickly (Truell, Alexander & Davis, 2004), neither observation is universally the case. Furthermore, students' typing speeds vary. Slow, two-fingered typists report that the effort of typing interferes with the process of composition or forces them to write more concise responses (Fluck, Pullen & Harper, 2009; Lee, 2002). In contrast, those who have been trained in typing and can type faster are in a stronger position to perform well (Kohler, 2015). Kohler (2015) raises the additional possibility that using inefficient cut, copy and paste techniques, and not using the 'undo' and 'redo' features, may slow students down when they are revising text. In psychological terms,

> … lack of fluency in lower order cognitive processes such as keyboarding or handwriting constrain higher order cognitive processes such as planning and reviewing. To this end, it might make sense that less fluent typists would be forced to spend more time on lower order processes as opposed to higher order processes that have to do with the content and organization of their ideas in essays (Kohler, 2015, pp. 140–141).

It would be erroneous to assume that faster typists necessarily produce lengthier exam responses. Indeed, Mogey and Hartley (2010) found no association between speed and the number of words produced. This may be explained, at least in part, by pauses for thinking and a greater time spent on revision (see section 3.2.2).

A number of authors conclude that proficiency has a stronger influence on students' e-exam performance than the amount of computer experience (e.g. Bridgeman & Cooper, 1998; Kohler, 2015). Indeed, in a dual-option situation (i.e. where students are given the choice between handwriting and typing an exam), 'it is the typing proficiency dimension that shows the greatest association with willingness to type in an examination, not the dimension capturing argument and coherence' (Mogey & Fluck, 2015, p.799).

Given that handwriting speed and style (printed or cursive) can have a similar impact on the finished product (Graham, Weintraub & Berninger, 1998; Connelly et al., 2005), the dual option (where allowed) can prove problematic for students. Augustine-Adams et al. (2001) offer four recommendations based on their statistical analysis of handwritten and typed exam scripts; their recommendations can be summarised as follows:

- If you are proficient at typing, type your exams.

---

[5] Exceptions are subjects in which students are required to handwrite formulae or hand-draw diagrams in weekly essays or problem sheets: e.g. Maths and Chemistry.

- If you are not proficient at typing, then it is better to spend time studying the substance of course than improving your typing skills.
- If your typing and handwriting proficiency are more or less equal, then take into account the legibility of your handwriting when choosing.
- Become a proficient typist before you come up to university.

Speed is not solely a function of an individual student's typing proficiency; it can also be adversely affected by the device used. This is particularly the case where students type their exams on unfamiliar institutional devices (Hillier, 2015a; Lee, 2002; Walker & Handley, 2016). Indeed, Walker and Handley draw a distinction between 'digital proficiency — reflected in the effective day-to-day use of technology for learning (e.g. from email to essay writing) — and IT proficiency for assessment, reflected in the capability to use unfamiliar technology under time pressure in computer-based exams' (2016, n.p.). One solution to the situation is 'BYOD' — students bringing their own devices to the exam — but BYOD has practical implications, as discussed in section 4.2.1.

On top of the pressure that may already affect students' intellectual processes (see section 3.2.1), introducing technology into the exam room may create additional sources of pressure: namely, computer anxiety and anxiety about technical failure.

Computer anxiety has been defined as 'the fear associated with interfacing with a computer that is incommensurate to the true intimidation given by the computer' (Shermis & Lombard, 1998, p. 113). However, although both Shermis and Lombard (1998), and Walker and Handley (2016) refer to computer anxiety in relation to their studies, neither article makes clear whether it actually has a detrimental effect on students' performance.

The second source of pressure is specific to the e-exams situation: anxiety about the reliability of the technology during the exam, whether institutionally provided or BYOD. In Hillier's (2014) study of students' preconceptions about e-exams, fear of technical failure emerged as a prominent concern. Yet, a study of students' actual experience by the same author (Hillier, 2015b) does not appear to have explored the extent to which they felt that this fear affected their performance.

3.3 MARKING E-EXAMS

3.3.1 PERCEPTUAL AND ATTITUDINAL INFLUENCES ON THE MARKING OF EXAM SCRIPTS

The research studies reviewed for this report suggest that a number of perceptual and attitudinal factors come into play as markers read and mentally process students' exam scripts.

Lee (2004) reports the negative impression created by 'severely illegible' handwriting, which participants in his study felt 'interrupted the smooth flow of reading and impaired their focus on content.' He suggests that, in comparison with typed scripts, handwritten scripts may exercise a negative influence where markers find themselves in a 'time-constrained testing condition' (pp. 13–14). In contrast, Powers, Fowles, Farnum and Ramsey (1994) refer to a 'reader empathy effect' between the marker and a student who handwrites their exam script, with the marker feeling 'closer to the writer' of a handwritten script (p.221). Powers et al. suggest that the marker may give the student the benefit of the doubt over illegible patches, or interpret crossings-out as evidence of the student's attempts to revise their work (and reward the student accordingly).

As noted in section 3.2.2, typed exam responses tend to be longer than handwritten ones. Yet, typed scripts give the visual appearance of being shorter than handwritten essays, even where their word count is the same or greater. In Powers et al.'s (1994) study, this remained the case even when typed scripts were subsequently transcribed into handwriting and vice versa (a method known as double transcription). This finding is important because research generally indicates a positive correlation

between the length of the response and the mark achieved, whether typed or handwritten (Augustine-Adams et al., 2001; Charman, 2014; MacCann, Eastman & Pickering, 2002).

A number of studies have reported on suspected differences in markers' overall expectations of typed and handwritten scripts (Lee, 2004; MacCann et al., 2002; Mogey et al., 2008; Mogey et al., 2012 ; Powers et al., 1994; Whithaus et al., 2008). It has been suggested that markers may expect typed scripts to be qualitatively different from handwritten scripts, as Whithaus and colleagues explain:

> It is tempting to think of the writing ability that is measured on a high-stakes exam as first-draft writing and therefore not subject to differences in composing materials. … Having the exams keyboarded seems to have shifted readers' expectations away from first-draft writing toward higher expectations associated with texts that have been more thoroughly revised (2008, pp. 12, 14).

Students in Mogey and colleagues' (2008) study suggest that the shift to typing their exams might lead markers to expect their responses to approach the same standard as the coursework that they type. This situation can be of concern to them as the standard of work expected an exam situation differs substantially from the standard expected from coursework (Mogey et al., 2008; Mogey et al., 2012): that is, there may be a difference in the marks achieved.

3.3.2 ON-SCREEN MARKING: INFLUENCE OF THE TOOL

If students type their exams and submit scripts in digital format, it arguably follows that academics should mark the scripts on the computer. A number of studies address the experience of on-screen marking (OSM), but only in relation to handwritten scripts that have been scanned into the computer. Even so, some of the findings may also be relevant to the marking of scripts in typed directly onto the computer.

Shaw (2008), and subsequently Johnson and colleagues (Johnson & Nádas, 2009; Johnson, Nádas & Shiell, 2009), investigated whether cognitive processes differ between marking on screen and marking on paper. In addition to slower reading speeds on screen (Shaw, 2008) and a greater cognitive load at first (Johnson et al., 2009), differences were found in reading strategies, navigation and awareness of spatial relationships within individual scripts, and annotation practices.

Shaw's (2008) work suggests that the mode in which an exam script is read (i.e. paper *vs* on screen) has an impact on the marker's reading strategy. Participants in his study reported that they were more likely to read in a linear fashion on paper and in a haphazard fashion on the screen. They also found it harder to skim-read scripts on the screen in order to elicit the salient themes of individual responses; instead, they had to resort to multiple readings. Shaw (2008) comments:

> If examiners construct meaning by processing at different levels concurrently in an interactive way then they must be able to apply simultaneously, elements such as context and purpose together with lexico-grammatical and discoursal features. If mode affects their ability to do this, then not only will a different reading strategy be employed on-screen but recovery of the intended meaning of a candidate's answer might be compromised when marking on-screen. (p. 267)

Regarding navigation Shaw (2008) notes that, in a paper document, the reader is readily able to form a visual representation and memory of a particular item of interest in a text. This is because they can establish *spatial awareness*: i.e. gain a sense of the position of the item on the page, and of the position of the page in the document. On the computer, spatial awareness is weakened if only part of a page is visible on the screen and the reader has to scroll to the item of interest. However, Johnson

et al. (2009) found that annotations could mitigate this problem by helping the marker to establish the required visual representation.[6]

Navigation is important not just in establishing textual meaning within an individual script. Markers may rely on also being able to navigate among multiple scripts in order to compare the performances of different candidates and to ensure that their judgements are consistent. Participants in Johnson et al.'s (2009) study reported that it can be harder to move between online copies of scripts than between printed copies.

Annotating exam scripts serves a twofold function: the 'public' function of communicating information from the marker to a subsequent reader, and a 'private' function, 'representing a moment where the text and the examiner's understanding of it come into direct contact' (Shaw, 2008, p.268). Both Shaw (2008) and Johnson and Nádas (2009) report that markers in their studies made fewer annotations on the computer screen than on paper. They suggest that this may be for two reasons: 1) the greater physical effort involved in making an annotation in a digital environment, and 2) a mismatch between the notations available and the notations that the markers would like to use.

Findings of investigations into the physical effects of marking on screen suggest that academics find it somewhat uncomfortable. Problems reported include eye strain (Coniam 2011; Coniam & Yan, 2016), soreness in the neck (Falvey & Coniam, 2010) and overall tiredness (Shaw, 2008), and appear to be associated with extended periods spent on the task.

3.4 DIFFERENCES IN PERFORMANCE

As with other aspects of e-exams, research comparing the actual marks achieved in typed and handwritten responses has yielded contradictory results. Among the studies read in detail for this report, higher marks were awarded to handwritten responses in the work reported by Bridgeman and Cooper (1998), Kohler (2015), Lee (2004), Mogey et al. (2010) and Powers et al. (1994). Higher marks were awarded to typed essays in the work reported by Augustine-Adams et al. (2001), Charman (2014), MacCann et al. (2002) and Whithaus et al. 2008). Lee (2004) found that handwritten responses received higher marks than typed responses when scored holistically, but the situation was reversed when responses were scored analytically (i.e. using a set of specified criteria). MacCann et al. (2002) also report discrepancies when scripts are marked holistically and analytically.

However, in almost all of the studies the differences between the marks awarded to typed and handwritten were not statistically significant. Even so, the difference may come as a surprise to students who believe they will perform better on the computer (e.g. Lee, 2002; Lee, 2004).

Reasons put forward for the higher scores awarded to handwritten essays include the greater visibility of errors in typed scripts (Kohler, 2015; Lee, 2004; MacCann et al., 2002; Whithaus et al., 2008); the greater perceived length of handwritten essays (see section 3.3.1); and the possibility that markers have higher expectations of typed responses (see section 3.3.1).

Researchers have also investigated the potential role of specific demographic characteristics in students' performance in typed *vs* handwritten tests. Gender and ethnicity are ruled out as influencing factors in Bridgeman and Cooper's (1998), and Augustine-Adams et al.'s (2001) studies. ESOL[7] status is also dismissed as a factor by Augustine-Adams et al. (2001); however, in Kohler's (2015) very small-scale research with eight ESOL students, six participants performed better in handwritten than in typed exams. The influence of age (in a taught postgraduate cohort) is

---

[6] 'Zoom' functionality and 'thumbnail' views of document pages in the on-screen marking software might also help in this respect.

[7] English as a second or other language.

speculated upon by Walker and Handley (2016), but they do not provide actual data to support or dispel this speculation.

There is a possibility that gender may have an influence on performance in dual option situations. When students in Mogey and colleagues' studies were given the choice, more male students opted to type than females, although the difference was more pronounced in the study by Mogey and Hartley (2013) than in the one by Mogey et al. (2012). Given that boys may produce more text, and their essays may be of higher quality, when they type their work (Dixon, Cassady, Cross & Williams, 2005), it is possible that the dual option may help male students to lift their marks. We did not identify any research studies in our survey that have investigated this hypothesis. (In Dixon et al.'s study, girls' performance was unaffected by the mode of writing.)

The lack of consensus among study findings may also be attributable to the settings in which the studies were conducted or to shortcomings in the methods adopted (Lee, 2004). For example, Mogey et al. (2010) observe that 'mock' exams or artificial settings can influence participants' attitudes. Bridgeman and Cooper (1998) noticed practice effects where participants were tested in both modes, regardless of which mode they took the test in first. Mogey and Fluck (2015) admit to differences between the cohorts that they studied in Edinburgh and Tasmania.

As well as investigating students' performance in typed *vs* handwritten exams, it is important to consider possible differences in the performance of markers. Indeed, Whithaus et al. (2008) specifically indicate 'the need to analyze how the medium of reading an exam impacts the raters' ability to apply assessment criteria.' (p. 14). Markers' performance can be evidenced in measures of severity, accuracy and inter-rater reliability.

Regarding severity, Whithaus et al. (2008) found that markers were no more severe on typed scripts than on handwritten scripts, despite the reported difference in expectations (see section 3.3.1). Johnson et al. (2009) detected no significant difference between scripts marked on paper and those marked on the screen: 'Where an examiner was severe or lenient in one mode they were also similarly severe or lenient in the other mode' (p.7). However, a subsequent study (Johnson, Hopkin, Shiell & Bell, 2012) found that markers were slightly more lenient on screen than on paper. It should be noted that the on-screen marking in the research by Johnson and colleagues was carried out on scanned handwritten scripts.

There are empirical indications that inter-rater reliability may be improved by the marking of typed scripts. Bridgeman and Cooper tentatively ascribe the improvement to 'the greater standardization in the word-processed essays in which raters cannot attend to differences in handwriting or overall neatness' (1998, p.4). The difference may also depend to some extent on the marking scheme adopted: Lee (2004) found greater reliability in the marking of typed scripts when they were marked holistically, but not when they were marked analytically.

On the basis of a comprehensive literature review on reliability, Tisi, Whitehouse, Maughan and Burdett (2013) suggest that on-screen marking tools may contribute to greater inter-rater reliability in two ways. Individual exam papers can be split up so that different individuals mark different questions (item-level, as opposed to paper-level, marking); and the collection of analytics makes it possible to detect inconsistent or inaccurate marking throughout the marking period and to take action where needed. Note, however, that Tisi and colleagues' review covered only the on-screen marking of scanned handwritten scripts.

The accuracy of a marker's performance is defined in terms of the proximity between the mark that they award and a 'reference mark' established by the principal examiner (Johnson et al., 2009). Its use may be more widespread in large-scale assessments in the secondary-school sector than in universities where the cohorts — and consequently the numbers of markers — are smaller. With different groups of colleagues, Johnson carried out two comparative studies of accuracy in the marking of printed and scanned handwritten scripts (Johnson et al., 2009; Johnson et al., 2012). In both cases, accuracy did not appear to be affected by the mode in which the papers were marked.

3.5 EQUIVALENCE: IMPLICATIONS FOR DECISION-MAKING

In a review article entitled *Computer- vs. paper-based tasks: Are they equivalent?*, Noyes and Garland (2008) refer to 'the need for equivalence to be determined fully to ensure that overall performance outcomes are matched' (p. 1357). Overall, they conclude that 'equivalence is going to be hard to achieve since two different presentation and response modes are being used. This will especially be the case with non-standardised, open-ended tasks' (p. 1371). In contrast, 'bespoke and closed' tasks can be made more similar in both computer- and paper-based modes.

Among the authors whose papers are surveyed in this report, Whithaus and colleagues (2008) stand out in considering that the processes of handwriting and typing do not differ significantly. For them, it appears more important that students are given the dual option so that they can choose the mode in which they feel the most competent. In contrast, Lee's (2002) findings suggest that:

> … the constructs measured in computer and paper modes are not the same. That is, the incorporation of computers into writing assessments involves a new way of thinking about composing processes, which introduces a source of variability in the original constructs. Inevitable sources of non-equivalence of the construct between them might lead to differences in test performance to some extent. (p. 152)

Our survey of the research literature leads us conclude likewise: typed and handwritten exams are not equivalent. The differences — in intellectual processes and in academic outcomes — may be qualitatively negligible and/or statistically insignificant, but they matter to students whose marks hover on the boundaries between grades. Some will benefit from a move to typed exams, but others will be disadvantaged.

The view that typed and handwritten exams are not equivalent rules out the 'dual option' as a solution for students whose typing is less proficient, or who prefer to handwrite their exams for other reasons. An alternative may be to make e-exams compulsory and provide students with opportunities to develop their typing proficiency in general (i.e. not just training in use of the e-exam tool).

4. PRACTICAL AND POLICY CONSIDERATIONS

4.1 PERCEIVED BENEFITS AND CONCERNS REGARDING E-EXAMS

This section considers the perceived benefits and concerns associated with e-exams, from the perspectives of academics (including markers), students and administrators (including the institutional perspective). Pedagogical innovations enabled by e-exams are listed at the end of section 4.1.1, and possible countermeasures to address concerns are listed in section 4.1.3.[8]

4.1.1 BENEFITS

There are several perceived benefits of a move towards e-exams, besides the obvious one of increased use of digital media by students in their everyday lives, as opposed to handwriting.

Academic perspective (teachers, markers, examiners)
- Exam grading may be simplified (and sources of error eliminated) by improving readability — it easier to read typed than handwritten responses.

- Anonymity may be strengthened with typed text, as handwriting may sometimes give away a candidate's identity (notwithstanding the fact that writing style may continue to be identifiable).

- On-screen marking (where the option is allowed or elected) can make life easier for the marker, in the sense of using electronic mark-up and commenting tools.

- Depending on the question type (e.g. so-called 'objective' questions), automated grading may be possible.

- Digital answer scripts are available instantly for marking.

- If matched with electronic marking tools and workflows, faster feedback could apply not only to computer-marked questions, but also to essay questions.

Student perspective
Section 3.1 provides more detailed information about students' experience of typing as opposed to handwriting in exams, including factors such as planning, composing and revising their responses

- In many disciplines, it is now the norm for students to type essays, assignments and other coursework. Thus they are more familiar and comfortable with typed input via digital media, than with the handwritten form. The writing process and media of pen-and-paper are simply not used in students' daily lives, and reverting to pen-and-paper for long examination sessions can have adverse consequences on their performance.

- Students' future employability skills and practice in the workplace can be enhanced if university examinations are conducted in a more authentic way (i.e. using tools similar to those they will encounter in the workplace).

- Students would benefit from the ability to correct errors when typing, as well as other affordances of word-processing software, depending on their proficiency in its use.

- Those students who are able to type faster than they can handwrite are in a stronger position to provide more extensive answers. (A similar comment would apply to the speed of handwriting in paper-based exams.)

---

[8] Information presented in this section has been synthesised from the following sources: Mogey et al. (2008), Fluck et al. (2009), Hillier & Fluck (2013), Hillier (2014, 2015a, 2015b), Sindre & Vegendla (2015a, 2015b), University of Bergen (2016).

- Students are familiar with digital tools and, in particular, the devices they own; they will therefore be more at ease being examined using a tool with which they feel comfortable.

- Students may experience exams as more meaningful and motivating if their knowledge and skills are tested in a more valid and reliable manner.

- In exams that require students to compose programming code, students would be able to compile and test the code during the exam instead of simply writing it down,

- Where appropriate, students would be able to use software for the statistical analysis of data, and solve mathematical problems numerically (see also pedagogical benefits).

- An e-exams platform would make it easier to collect and provide a bank of previous digital exam papers (if desired), for student preparation, or for discussion in class.

- Students may be able to receive their results more quickly (depending on marking processes).

Administrative and institutional perspective

- Workflows and work process can be streamlined and set up well in advance to avoid heavy workloads during exam periods.

- Invigilators no longer have to distribute paper exam questions or collect answer scripts.

- Manual tasks can be reduced (e.g. collecting, sorting, copying, forwarding, archiving), which in turn reduces the risk of manual errors.

- Markers can receive the exam responses electronically and (depending on the system and the requirements) may be able to compare their grading decisions with other examiners.

- It is easier and faster to archive exam papers and retrieve previous papers. It also reduces the need for physical archive space.

- Quick and easy access to the electronic archive of answers, marks and comments would facilitate the handling of complaints or appeals.

- Costs may be reduced due to the electronic nature of preparing and administering e-exams and presenting the questions on-screen, as well as distributing answer scripts to markers.

- Digital question papers might make it easier to adapt the exam to students with special needs, or to students located at a distance from the normal exam venue.

- Student ownership of laptops is now providing a ready resource and minimising the costs associated with institution-owned equipment. (However, see the concerns about BYOD in section 4.2.1.)

- Online exams, which students sit off campus (e.g. take-home exams), offer a way to expand capacity in order to cope with increasing student numbers, limited physical venues and constrained budgets (this is not applicable to the current E-exams project).

Pedagogical perspective

- E-exams should offer opportunities to reflect on assessment methods (and their strengths and weaknesses), what an exam actually tests, and how it should be an integral part of the subject and test the desired learning outcomes. This increases validity of the assessment, which is a growing requirement for quality assurance.

- E-exams should offer opportunities to create a comprehensive and well-aligned learning and assessment environment, taking into account the realities that graduates will face in their careers.

- '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 the setting of much more authentic assessment tasks characteristic of a twenty first century problem

environment' (Binkley et al., 2012 cited by Hillier, 2015b, pp. 143-144)… [it opens up] 'the "pedagogical landscape" in the exam room' in the following two ways (Hillier, 2015b, p. 143):[9]

- New types of test items can be enabled, e.g. incorporating additional materials such as audio, video, medical case studies, 3D engineering models and industrial tools.

- Real-life tools that fit the task can be provided to students to use in formulating their responses, e.g. statistical analysis tools, datasets to use in writing computer algorithms, computer programming languages and project management tools.

4.1.2 CONCERNS

Any move towards increased use of digital technologies in the assessment process is likely to attract objections and concerns, for a variety of reasons, listed in this section.

Academic perspective (teachers and markers)

- There may be resistance from markers to marking on screen; consider making provision for downloading and/or printing the answer scripts to enable marking on paper.

- Giving markers the dual option (of marking on screen or marking on paper) has complex implications: marking on screen changes the way that markers read and mentally process the script and can in theory affect the marks they give — see section 3.3.1.

- External examiners may find the transition more difficult than academics who teach the course, since examiners are usually part of the assessment process only on an irregular basis. It may take external examiners longer to become confident in using an electronic system; and they may also be harder to reach with communication, support and training.

Student perspective

- Students may be concerned about academic integrity (i.e. the potential for others to cheat and what the institution is doing to minimise this risk).

- A major concern for students is reliability and stability of the equipment and software, so that the exam can be completed without technical errors or failures.

- Some students have been concerned about distractions in an e-exam such as keyboard noise and audible alerts from computers. These need to be minimised so that candidates can concentrate on formulating their responses.

- Some students may be concerned about their typing proficiency (compared to handwriting exams) and comfort with keyboards, browsers and operating systems (if not using their own devices) — see research findings in section 3.2.3.

- Students need to feel confident that the technology will not introduce additional stress and anxiety on top the pressures of the exam itself — see research findings in section 3.2.3.

- At the start of a transition to e-exams, students (like academics) may display some resistance to change (moving away from familiar pen-and-paper exams).

Administrative and institutional perspective

- Sustainability: additional resources made available for pilot projects (e.g. technical support, monitoring and additional invigilators) may not be sustainable for a service when it is rolled out across the institution.

---

[9] The need for equivalence between the exams would render this difficult, if not infeasible, in situations where students have the dual option of handwriting *vs* typing.

- Scalability: pilot projects with small numbers of students writing formative exams do not necessarily scale to large numbers of students and/or high-stakes exams. This is particularly problematic if university computers are required, in suitably equipped labs.

- Reliability of technology and associated infrastructure: any technical malfunctions can affect many students simultaneously. For example, if the whole network should fail, the examination would need to be rescheduled.

- Security: more opportunities exist for academic misconduct, especially in a BYOD setting; for example:
    - copying and pasting from internet sources;
    - copying and pasting from unauthorised materials on the computer, a mobile device or a memory stick (small objects can be more easily passed between candidates, either in the exam room or by using the toilet area as a mailbox);
    - electronic communication between candidates in the exam room;
    - help from outside individuals (e.g. email or audio received from a hidden Skype call);
    - observing neighbours' answers in a computer lab where screens are angled in an upright position.

- Invigilators need to follow new instructions, be aware of new forms of cheating, and undergo training in using the digital platform and troubleshooting student problems.

- Investment in infrastructure: if using BYOD, costs will be incurred in providing more and better wireless connectivity and power provision.

4.1.3 POSSIBLE COUNTERMEASURES

Certain measures have the potential to overcome many of the difficulties associated with using computers in the exam room.

Technology issues
- Additional connectivity (portable Wi-Fi masts) and power supplies (spare battery packs) can be provided.

- Hardware certification: IT experts can check student-owned devices for suitability and fitness for purpose.

Software issues
Most e-exam platforms claim to lock down the computer and/or the browser, so that students have access only to the exams platform to type and submit their responses. (However, the efficacy of such security measures has been questioned, and no software platform can ever be certified as completely 'unhackable' — see section 4.2.1).

Academic integrity issues
- Measures can be taken to strengthen invigilation practice, for example, invigilators need to be aware of, and know how to deal with possible unauthorised use of technical tools and methods during the e-exam.

- Automated plagiarism checking is usually built into e-exams systems, making it possible to identify any copying and pasting from other sources.

- E-exams platforms allow synchronous central monitoring of candidates' activity, so any sudden appearance of a large number of characters in an answer script can be identified.

Sindre and Vegendla (2015b) propose the following measures in attempting to curtail opportunities for cheating:

- Mixed seating: it is possible to present e-exams in various different courses to a mix of students seated in the same physical room (to prevent whispering, peeking or passing physical information).

- Non-uniform questions: randomising question topics or materials provided (e.g. datasets for computer science students) is easier with e-exams.

- Moving calculators and books into the e-exam system: permitted written resources and tools can be provided digitally on the e-exam platform, so that students do not need to bring their own books or other equipment into the physical room — nor would these need to be provided by the institution.

4.2 TECHNOLOGY

This section reports on the use of student-owned devices in formal examinations, followed by features and additional possibilities enabled by commercial e-exams platforms.

4.2.1 STUDENT-OWNED DEVICES (BYOD)

Laptop ownership amongst today's university students is known to be high (Macleod & Paterson, 2012, cited by Mogey and Fluck, 2015; Hillier, 2015b). Given the cost and infrastructure requirements for an institution to provide sufficient computer facilities for students to type examinations, many pilot projects have opted for students typing their answers using their own devices ('bring-your-own-device': BYOD). However, according to Dawson (2016), 'the BYOD e-exam is by definition less secure than both pen-and-paper examinations, and examinations held in a computer laboratory, as it has all the vulnerabilities of both environments, as well as some of its own' (p. 598).

Concerns with using BYOD

The biggest concern about students using their own devices in an exam is that the institution has no control of the device and how it has been set up. Tech-savvy students can install virtual machines (or use other methods unseen by invigilators), enabling them to circumvent security functions of the e-exams software and access unauthorised materials and sources of information. Dawson (2016) warns that creating scripts to disguise running a virtual machine or accessing external sources is within the abilities of a typical information technology student. Hillier and Fluck (2013) concur that since student-owned devices come with a diverse array of operating systems and software applications, the use of these devices is 'fraught with complexity' (p. 387).

A web developer from Stockholm, Hannes Aspåker (2016), wrote a blog post sub-titled *Why it is impossible to lock someone out of their own computer*. He describes in some detail the general process of how to disable certain parts of an application, a method which can be applied to any e-exams system. He claims that it takes only 15 minutes to disable any attempt on the part of the software to prevent cheating: '10 minutes to find the relevant sections and 5 minutes to modify the machine instructions'.

Indeed, Oxford's own developers were able to carry out such a 'hack' within 15 minutes, during a demonstration by one of the leading e-exam software providers (and one with very public exposure). This vendor admits that security in BYOD is a game of 'cat and mouse'.

On the other hand, Sindre and Vegendla (2015b) are of the opinion that claims about the vulnerabilities of BYOD e-exams are exaggerated, and that it is not obvious that BYOD e-exams will generally be less secure than paper exams. They point out that, even if e-exams introduce new threats, they also enable many countermeasures against cheating (see section 4.1.3). These authors conducted a comparative analysis of cheating-related security threats and countermeasures of

paper-based exams versus BYOD e-exams. They argue that 'if e-exams have advantages in other respects they need not have better security than traditional paper-based exams, only a similar level of security' (Sindre & Vegendla, 2015b, n. p.), and conclude that neither examination method has a clear advantage from a security perspective.

Requirements for BYOD

The feasibility of using BYOD at scale and in high-stakes exams remains rather dubious. Besides security issues, BYOD would require the following infrastructure and support (Damion Young, personal communication, 6 April 2017):

- equipping a room or rooms in Exam Schools with power points for each student, or alternatively buying and maintaining portable power packs that are device-agnostic;

- providing a small bank of devices for loan to those students whose computer goes wrong before or during an exam. These loan devices would need to be maintained and have software updated;

- meeting greater demands for technical support during an exam: wireless connectivity, hardware problems, etc.;

- dealing with greater demands on invigilators to spot unusual IT behaviour. The experience in the Medical Sciences Division is that very few invigilators have the technical literacy to spot issues on the computer.

Other problems with BYOD

Students have a lot invested in the use of their own devices regarding their studies and privacy. They 'do not like their personal equipment and software to be interfered with or breached by exam software' … which can be 'intrusive, often installing and leaving behind some components that may interfere with the ongoing operation of the computer' (Hillier & Fluck, 2013, p. 387). Students' devices may be incompatible with the exams software, and may be running out-of-date operating systems or other software. Thus students will need to be willing to subject their devices to testing, and they themselves will need to download, install and test the exams software well in advance of the exam.

The Medical Sciences Division at Oxford has experience in running high-stakes objective exams (i.e. multiple choice-type questions) using Questionmark Perception (see Appendix A). They are of the opinion that:

> BYOD will inevitably introduce far more technical issues during exam delivery — even with our IT suite-based exams for up to 90 students per sitting, we regularly have technical problems which delay the start of, or interrupt exams. As one can imagine, the situation can become quite charged, with highly-stressed students. For one exam about five or six years ago, half the students saw a slightly different presentation of the exam because of a different operating system, which led to complaints (Damion Young, personal communication, 6 April 2017).

4.2.2 E-EXAM PLATFORMS

Features

Most e-exam platforms are cloud-based, with particular software that needs to be downloaded onto user computers. If using their own devices, students will be required (in advance of the exam) to download, install and test the software and/or a lockdown browser, depending on the particular platform requirements. Student computers need to be fit for purpose: that is, equipped with latest internet browsers to download the software, anti-virus protection etc.

The software purportedly locks down the computer and prevents access to anything other than the examination software, although the detail of how this is achieved differs among various platforms. Students type their answers into a word-processing interface. Features such as auto-correct and spell checking can be enabled or disabled; academic staff can specify which configuration is appropriate for each examination.

Some systems enable typing of special characters (e.g. foreign languages, mathematical notation). In many subjects, it is necessary for students to draw a diagram to support an answer — some systems allow students to insert a hand-drawn diagram, or to take a photo of a hand-drawn diagram and attach it to their answer script.

Additional possibilities

In order for the institution to maintain control of computers used for e-exams, it has been suggested that a portable bank of Chromebooks (or tablets-with-keyboards) could be purchased, stored in lockers and checked out to students to use during the invigilated exam.[10] However, compatibility of such devices with the software will need to be carefully checked, and not all e-exams software platforms will necessarily support Chromebooks.

In attempting to circumvent some of the risks of students typing examinations **online**, universities in Australia have trialled an invigilated, **offline** computer-based assessment system using the Ubuntu operating system on student-owned devices. Students are required to boot their laptop using a pre-formatted USB storage device (Fluck et al., 2009; Hillier, 2015b). However, special skills are needed to install, run and maintain the open source system; also, students would need to learn the rudiments of the Ubuntu operating system and Open Office Writer for word processing.

4.3 THE E-EXAMS PROCESS

According to Bausili (2017), 'within an institution, the identification of major workflows is fundamental to both an effective implementation of assessment technologies and in conducting change' (p. 1). The same author found from her review of pilot projects on e-submission and e-marking, that the experiences of early adopters (or enthusiasts in a pilot project) 'failed to alert institutions' (p. 7) to two aspects implicit in adopting electronic assessment methods: the reluctance of subsequent participants to adopt such methods; and the major cultural shift required in staff practices.

It is helpful to consider three stages in the process of running an e-exam (adapted from Sindre and Vegendla, 2015a):

- **Preparation**: creating, sharing (with other examiners), and secure storage of examination question papers prior to the exam

- **Delivery** (conduct of the physical exam): venue, power, network connections, invigilators, online monitoring, IT support, spare devices, contingency plans

- **Post-processing**: saving and submitting electronic answer papers, collecting paper answer sheets (if used in conjunction with electronic submission), distribution to markers, marking process (recording and submitting marks and providing feedback, if applicable).

Jisc (2015) developed an 'assessment and feedback lifecycle' which tends to focus on formative assessment and feedback. Figure 4.1 overleaf is a visual representation of suggested stages in the e-exams process, synthesised from Jisc (2015) and Sindre and Vegendla (2015a).

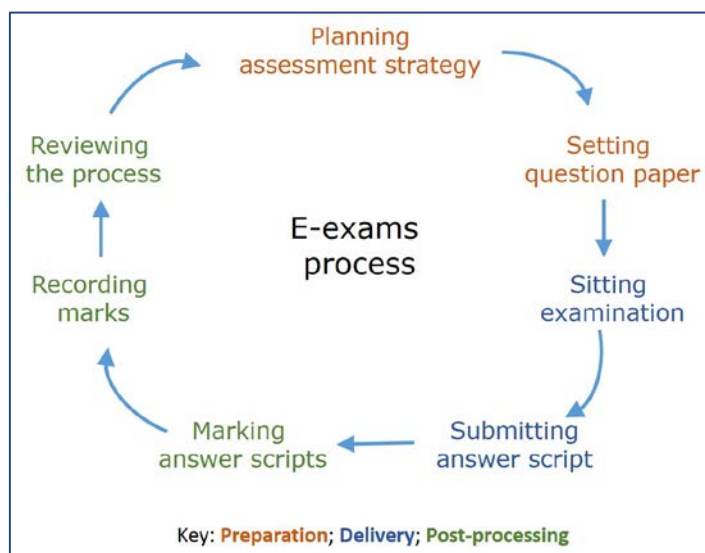[10] See the example at https://www.lapsafe.com/products/diplomat/lms

Figure 4.1 Stages in the e-exams process (adapted from Jisc, 2015; Sindre & Vegendla, 2015a)

Figure 4.2 illustrates more detail in a standard examinations workflow, including the role players involved at each stage[11]. The activities in pale boxes (with dashed borders) exist solely for the paper-based process and might be dispensed with[12] when conducting e-exams.
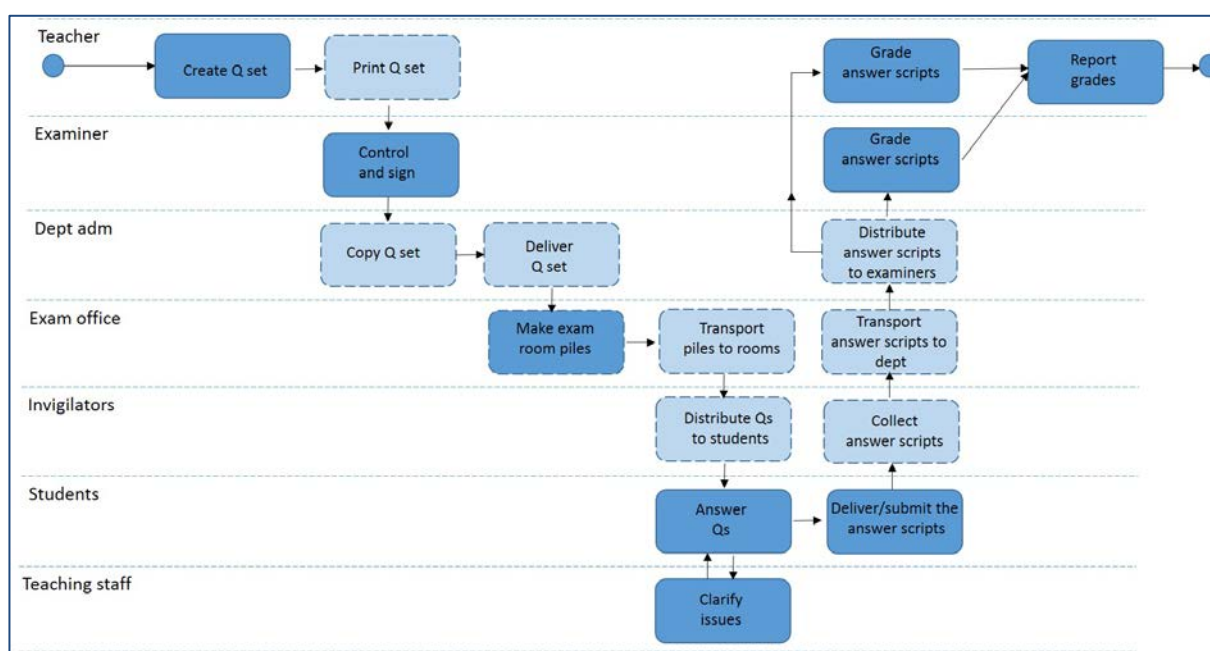

Figure 4.2 Typical examinations workflow (adapted from Sindre and Vegendla, 2015a, p.4)

Sindre and Vegendla (2015a) describe possible process improvements and other savings when implementing e-exams:

- Many activities (before, during and after the exam) may not be needed for e-exams (see the boxes with dashed borders in Figure 4.2). Further gains in terms of saving time and reducing errors may be gained when investigating sub-tasks more closely, e.g. 'Report grades' — some

---

[11] The actual processes at Oxford University are likely to be more complicated than shown here, and extremely diverse across exam boards. The recent Assessment Results Management project has been put on hold while possible process simplification is considered.

[12] Savings on paper and ink would not be applicable if a paper-based copy of the question paper is provided for e-exams.

administrators maintain the grades in spreadsheets and have to type them into the central system (time could be saved and human error avoided).

- Better avoidance of errors in questions and delivery of question papers — e.g. formulation of questions, poor or incomplete copies of printed question papers, distribution errors (where candidates may be spread across several exam rooms).

- Quicker and fairer correction of errors and clarification of queries during the exam — the teacher can broadcast the same correction message to all candidates at the same time, improving both validity and fairness of the exam, while reducing stress for the teacher.

- Saving costs of materials — primarily paper, ink, hardware items for printing and copying

- More flexible parallel grading — authorised markers (examiners) can access the electronic answer scripts immediately after the exam, synchronously, and in different geographic locations.

- Markers can grade the exam per question across all candidates (if this is the preferred practice), rather than candidate by candidate — for a digital exam, markers could be offered the choice.

Implementing an e-exams system is complex and demanding because the transition from paper-based to digital assessment demands that all role players need to collaborate and plan well in advance. They may also have to change or adapt well-established and well-known routines (Jensen, 2015). Furthermore, much is at stake for everyone involved in the examining and assessment process, not least the students. The real challenge is often not the implementation of the technical platform itself, but addressing all processes involved in running exams, taking into account all role players involved. Bausili (2017) confirms this crucial need for a detailed understanding of all the business processes around assessment practices within the institution.

4.4 POLICY ASPECTS

Key factors to consider for e-exams across the institution include leadership and institutional culture, stakeholder engagement, system functionality and reliability, support and training.

A question about the use of e-exams was put to the ARC Assessment Practitioners Group in August 2017. Responses were insubstantial, with most institutions being interested in the possibilities, but not having implemented e-exams, especially not at scale. The anonymous responses included:

'We are in the same position as you: we only offer computer-based exams to students with individual needs but are beginning to think about a future shift away from paper to computer-based exams.'

'Whilst there are clear advantages of online exams, there are times when our IT resources can only just meet the demand for the very large modules.'

'We do not allow students to use their own devices because of the risk of academic misconduct and the current Ransomware threats are an additional consideration.'

'We have a large number of students with additional needs, many of whom also require the use of a PC so this adds to the demand for limited resources.'

'There would a tension for us in asking that all students provide a laptop to take an exam. We couldn't commit to providing one for students who don't have one.'

Bausili (2017) found at the University of Manchester that 'the effective adoption of these technologies requires a managed approach, especially a detailed understanding of current assessment practices within the institution and the development of new or adapted business

processes' (p. 1). This is particularly true at Oxford University with its diversity of examination and assessment practices across departments, faculties, schools and colleges.

The electronic management of assessment (EMA) needs to follow a staged roll-out across an institution, if pilot projects or trials have indicated that this is the desired path. Jisc has done some work on EMA and produced two reports (Jisc, 2007, 2010), although the technology and possibilities have since expanded quite substantially.

5. REFLECTIONS AND RECOMMENDATIONS

In compiling this report on the current landscape of e-exams in the UK and other nations, we have brought together the findings of scholarly research into the intellectual processes and academic outcomes of e-exams, with the practical experiences and insights gained from trials and larger-scale implementations.

Although findings of research into the psychological and academic aspects of e-exams are inconclusive and contradictory, they prompt a number of questions that will need to be considered if the trials lead to wider implementation in the University. The central issue is whether typed and handwritten exams are equivalent. As authors of the report, we have taken the view that they are not. This view has implications for practical decisions such as offering students the dual option between typing and handwriting their exams. Other readers might disagree, or consider that the differences are less important than students' right to choose between pen and keyboard.

The marking of e-exams is another area for careful consideration. Do markers treat typed responses akin to coursework essays and, therefore, expect higher standards? If yes, then there may be ramifications for rubrics and grading. Also, if marking typed scripts on the computer improves reliability, a case could be made for compulsory on-screen marking. Yet, such a move would have implications for the freedom of academics to make their own decisions.

As the above examples suggest, changing the tool used in a particular activity can (even should) prompt a reassessment of the activity itself. Switching from handwritten to typed exams not only brings summative assessments into line with coursework in terms of the tool in which students compose their submissions; it also raises deeper questions about the purpose, nature and validity of exams as a form of assessment:

> … when the stress in the course work has been on word-processed output, then handwriting extended prose under exam conditions could be regarded as a poor alignment of assessment practices with intended learning outcomes (Biggs 1999) and further, it may not be an accurate reflection of the quality of work the student is capable of producing. (Mogey et al., 2008, p.39)

Such bold considerations lie beyond the remit of both this report and the E-exams project as a whole. We concur with the counsel offered by Walker (n.d., online): 'Technology offers significant opportunities for us to reimagine the dominant modes of assessing and providing feedback in higher education but in an area where the stakes are so high transition rather than transformation may be necessary.'

RECOMMENDATIONS

Based on the research and experiences of other institutions in trialling or implementing typed, timed examinations, we offer the following recommendations to inform the E-exams project at the University of Oxford.

1. Technology

Formulate a clear technology plan to boost wireless connectivity and provide adequate power points in the exam venue. Maintain and provide sufficient numbers of loan computers and battery packs if implementing 'bring your own devices' (BYOD). Students need to be willing to subject their devices to testing by IT experts to certify their robustness and suitability; and students will need to download, install and test the exams software well in advance of the exam. Failure to check, monitor and augment hardware provision would run the risk of lost, incomplete or corrupted student responses in the e-exam.

2. Security

Subject potential e-exams systems to expert IT scrutiny in terms of the efficacy of claims regarding locked-down browsers and desktops (while being aware that no e-exams platform can be certified as 'unhackable'). Provide specialised training for invigilators and staff who are monitoring the e-exams platform during the exam session, to enable them to identify unusual IT behaviour.

3. BYOD

If planning to allow BYOD, mitigate the concomitant multiple risks of a serious nature, for example, academic integrity, loss of responses, unsuitable student-owned devices. Consider also the impact on students who may have to switch from computer to paper midway through the exam, or from their own device to a university computer. Such contingencies are likely to impact the workflow in having to allow more time for the student, provide additional supervision, and match up multiple parts of a student's submission.

4. Communications

Develop a communications plan to ensure that all role players involved in the implementation of e-exams receive clear information and communications in a timely manner. If students are to be offered the dual option — i.e. between handwriting and typing exams — they need to be informed of the advantages and disadvantages, and given enough time to make and confirm their decision. Pilot studies at other institutions have illustrated the crucial importance of coordination and communication with and among all those involved.

5. Workflow

Establish efficient institutional workflows for e-exams, with the aim of enhancing security and minimising manual processes. This should include the three process stages mentioned in section 4.3: preparation, delivery and post-processing of the e-exam. Institutional consideration should be directed to financing ongoing technical and procedural support for e-exams, including human resources required.

6. Students' IT proficiency for assessment

Prepare students for e-exams so that they can concentrate on demonstrating their knowledge of the topic rather than having to grapple with the medium and mechanics of production in an e-exam. Offer practice sessions to students in advance, exposing them to the e-exam platform and allowing practice in how to use it. Besides becoming familiar with the software, support students in improving their overall typing proficiency — not only typing speed, but also fluency in the use of the keyboard, keyboard shortcuts, electronic text-editing methods etc.

7. Markers' IT proficiency for assessment

Provide information, training and support to markers and build an on-screen-marking mind-set, where feasible and appropriate. It appears that inter-rater reliability could be improved and fairness enhanced by marking typed scripts, either on paper or on screen.

8. Rationalisation of technology

Select an e-exam platform that can accommodate computer-marked questions (objective test items), as well as essay-type questions, so that both modes can be offered to departments as a possible future service.

9. Ergonomics

Consider the ergonomics of students sitting and typing for long periods, i.e. the importance of correct posture, lighting, furniture and desk space beside the computer. Although it is clear that students who handwrite exams for several hours can suffer from physical problems such as hand cramps and neck strain, the effects of sitting hunched over a computer for two or three hours per

day, and possibly for three days on end during a formal examinations period, do not seem to have been taken into consideration in the research reviewed for this report.

10. Evaluating the trials

Conduct a formal evaluation of the e-exams trials to take place at Oxford University during Trinity term 2018. Appendix B provides details of the methods and instruments used in studies at other institutions to evaluate the reactions of students and staff to the experience of sitting and marking e-exams.

APPENDIX A. EXAMPLES OF DIGITAL ASSESSMENT

This appendix supplements Table 2.1 in section 2.2. It provides additional information about the experience of ten other universities in piloting or implementing e-exams systems.

OXFORD UNIVERSITY

We begin by summarising current practice at Oxford University in terms of e-assessment, both formative and summative, including expressed needs.

MEDICAL SCIENCES DIVISION

(Information gathered from personal communications with Damion Young, April 2016)

The Medical Sciences Division uses Questionmark Perception (QMP) for over 160 online assessments delivered to over 17,000 participants. Over 50 of these assessments are formal University exams with Exam Schools invigilators and students wearing the regulation subfusc. Although the majority of question types provided by QMP are computer-marked, it is possible for students to type answers to essay-type questions, which the lecturer marks later.

Courses which use QMP (for formative or summative assessments) include:

- Medicine (pre-clinical, clinical and graduate entry)
- Experimental Psychology
- Diploma in Paediatric Infectious Diseases
- MSc Radiation Biology
- MSc Clinical Embryology
- MSc Musculoskeletal Sciences
- MSc Integrated Immunology

For formative exams, the system is accessed through WebLearn. For summative assessments, the Medical Division Learning Technologies team wrote their own Basic LTI tool to launch the exam, in the interest of enhancing security.

Work has been done to enable **computer marking** of short essay answers and algebra problems, funded by the Innovation Challenges scheme:

- Typed algebra and typed numeric answers which 'understand' units and significant figures, decimal places, etc. This functionality is already in use as they simply updated an existing plug-in
- Typed free text answers to closed-ended questions up to a short paragraph in length — in conjunction with Stephen Pulman from Computer Science. This work was delayed while waiting for a Proctors' decision on using anonymised written exam answers to 'train' the system.

The team has written other customised tools for self-testing by means of **computer-marked** questions: MedLearn and iCases.[13]

Medical Sciences would be pleased if the software that this project tests also provides the functionality they need to run computer-marked assessments so that the University could benefit from the economies of scale, shared knowledge and support that might become available.

---

[13] See http://www.medsci.ox.ac.uk/support-services/learning-technologies/learning-teaching-and-asssessment/medlearn
and the example of an iCase at https://history.medsci.ox.ac.uk/outbreak_public/

CONTINUING EDUCATION

(Information gathered from personal communications with Marion Manton, April 2016 and 8 August 2017)

Summative online essays (assessed coursework) are submitted through customised Moodle assignments tool (MASS: Moodle Assignment Submissions System).[14] MASS submissions are now becoming the norm in more recently-approved courses that have moved away from 'old-style' sit-down invigilated exams. However there are still some historical courses, for which the regulations require formal exams written on paper, under examination conditions.

The Quiz tool in Moodle is used for lots of self-assessment, but formative only (nothing summative). The most interesting and sophisticated example of adapting the Moodle Quiz tool, both technically and pedagogically, is the work done for bridging courses in MPLS. This uses diagnostic quizzes that provide students with customised feedback per answer option, with links directly to the relevant learning materials, depending on their knowledge gaps.[15]

DEPARTMENT OF ENGINEERING SCIENCE

The Department of Information Engineering has a need to examine students' computing skills which cannot be adequately tested in a formal, invigilated written exam. The desirable exam format would be a discursive part describing the context and the data, and a 'hands-on' part in which students write algorithms in MATLAB and run them using data provided to produce the required output. At present the conventional handwritten exam consists of 3 or 4 questions, lasts 1½ hours, and allows no easy way to write or generate computer code.

The following possibilities for e-exams have been considered by the department:

Model A: Invigilated exam (summative) using computers provided by the University

A proposal was accepted by Education Committee in 2016 to offer an invigilated exam where students are provided with both paper on which to write/draw, and a computer with the candidate already logged in, on which they can type and run their computer code. Software requirements include MATLAB and possibly Python.

The Proctors raised the following concerns which currently still need to be addressed:
- Copying from a neighbour if the computers are too close
- Possible power failure or IT technical problems
- Allowing students to raise a hand for assistance (e.g. if stuck on the syntax of the code)
- Providing an equivalent alternative paper-based exam for contingency purposes
- Catering for candidates with special arrangements.

Model B: Take-home exam (formative)

Approximately 50 to 80 students usually take the Information Engineering option. There is a plan to run a take-home (formative) trial exam at the end of Hilary term 2018, using the IT infrastructure in the department.

The departmental IT system can handle the following requirements:
- Licences for MATLAB
- Providing access to data on which to run some algorithms
- Randomly generating sample data so that each student receives a different dataset
- Students submitting their completed file/s via a WebLearn anonymous submission site.

---

[14] MASS was intended to be an interim solution, pending handling of online submissions in SITS, which has not happened.

[15] See http://blogs.it.ox.ac.uk/ltg-casestudies/2015/10/13/mpls-maths-bridging/

BRUNEL UNIVERSITY, UK

Brunel University has run two pilots of high-stakes digital examinations (2015–2016; 2016–2017) using the WISEflow EMA platform. The second pilot was funded by Hefce (£50k). Students were offered the choice of using their own devices — the numbers who elected to do so were 72% and 84% in pilots 1 and 2 respectively. The remaining students were offered loan devices (25 loan laptops were on standby in the exam room), or were allocated space in a PC lab. During May 2017, 18 digital exams were successfully conducted. Student numbers ranged from 17 to 218, and a total of around 1600 electronic submissions were made. The team plans to start a staged roll-out across the institution in September 2017.

Their main questions in Pilot 1 where:
- Does the platform work?
- How do the stakeholders react?

Their main questions in Pilot 2 were:
- Can we scale it?
- Can we build the support?

Findings: Students were 'unfazed' by using their own devices to type exams, and there was limited uptake of the practice sessions offered. They reported that it is easier to compose structured work digitally, compared to handwriting. Predictably, there were problems with connectivity (additional Wi-Fi masts were required to boost connectivity in the exam room), battery life (considering buying spare battery packs), and student devices being unfit for purpose. Student assistant learning technologists (SALTS) provided support and assistance to staff and students before and during the exam sessions.

Administrators were optimistic about the software, but they were concerned about associated processes, workload for them (running two systems) and reliability of the technology. Since academics tend to harbour unconscious bias towards such platforms to enable electronic exams (e.g. "This won't work in my subject"), the team deliberately chose a wide range of academics to participate in the pilot projects. Those academics who were involved reported "massive" advantages in scripts being easier to read, and the inbuilt feature of plagiarism screening.

CAMBRIDGE UNIVERSITY, UK

Cambridge University ran a small proof-of-concept project in April 2017, in response to their Digital Education Strategy and to raise awareness about the various possibilities. Very careful planning took place during the 18 months leading up to the exam sessions, including back-up plans to cover technical, connectivity and other potential problems. The sessions took place across multiple venues, all of which required technical support to be on hand. Two departments accepted the invitation to run summative exams using the DigiExam software platform: Classics (10 students, two exam papers) and History (193 students, one main exam paper).

Students were surveyed in advance regarding their perceptions of E-exams, the perceived benefits and concerns, and the configuration of their own devices. They were offered the choice of typing or handwriting, and the pilot was strictly 'opt-in'. Students could choose at any time to change from typing to handwriting, even during the exam; in the latter case they were moved to the handwriting room (this caused a problem with matching the two parts of their answer scripts). They were offered the option of attending a practice session prior to the exam and if they elected to type, they were required to write and submit a text exam by a specified deadline. Comprehensive help web pages and FAQs were built, and self-enrolment in an online help course was available.

UNIVERSITY COLLEGE LONDON (UCL), UK

UCL conducted a trial with students from the Faculty of Laws in a mock examination during Jan 2011. This was a very small pilot in one faculty, with low student numbers. Students used their own laptops to type, rather than handwrite, their answers in otherwise traditional essay-style exams.

The pilot highlighted some issues and challenges, in particular the lack of student engagement and heavy staff resource requirements. The small-scale pilot took approximately 300 hours of staff time (admin staff and technical support). Given the lack of take-up, and the remaining issues and questions, our current information reports that they did not move beyond a pilot to Phase 2.

UNIVERSITY OF EDINBURGH, UK

In 2006, the University of Edinburgh ran a pilot using Exam4, which was then used for nine years; however, uptake was low and the system was rather limited in what it could do (for example, no on-screen marking). They retired it as a service in 2016, but almost the minute they did, interest suddenly piqued, especially in the College of Science and Engineering. Their Dept of Biology is interested in the ExamOnline platform (used by the University of Dundee — see separate section in this appendix). Since interest in digital essay writing is gaining momentum, and the university does not currently offer a centrally supported service, they plan to review possibilities in the coming year (Jo Spiller, Head of Educational Design & Engagement, University of Edinburgh, personal communication, 16 August 2017).

The earlier pilot projects at the University of Edinburgh involved essay examinations, rather than short answers or other types of electronic assessment. In some disciplines, students had a choice as to whether to use their own laptop or to handwrite the exam — loan machines were made available for those students who preferred to type, but did not have their own laptops (the amount of loan machines required was small, since student laptop ownership in Edinburgh is high). Students downloaded and installed the exam software onto their own laptops prior to the exam.

For students sitting the same examination, in the same venue, some used pen and paper and others a keyboard. The exam question paper was handed out on paper to all candidates. After completing their answers, the encrypted digital scripts were submitted via the wireless network to a server; handwritten scripts were collected in the usual way. 'Marking continues to be done on paper, although in the future, digital scripts could be marked on-screen' (Mogey & Fluck, 2015, p. 794). Several research studies emerged from their pilots with Exam4, focusing on student choices and performance comparing typing and handwriting exams (as reported elsewhere in this document).

OPEN UNIVERSITY (OU), UK

The OU ran a small pilot of online exams during the academic years 2013-2015, involving 200 students from 10 different modules. They used a locked down Wi-Fi access point running a customised Moodle server which distributed the exam and saved the student submissions. The exams were conducted in both OU and non-OU exam centres. Students used their own laptops on which they had previously installed the safe exam browser (SEB)[16]. They typed their responses directly into essay-style questions in a Moodle activity (Quiz or Wiki); input was text only. Each student was provided with a hard copy of the question paper for reference and an answer book for rough working.

---

[16] "Safe Exam Browser is a webbrowser-environment to carry out online-exams safely. The software changes any computer into a secure workstation. It regulates the access to any utilities and prevents students from using unauthorised resources" (from https://sourceforge.net/projects/seb/).

As each exam centre had only up to 10 students during any one sitting, each student had an individual power socket for their laptop. Some technical issues were encountered, mostly to do with Wi-Fi issues. Invigilators were present throughout. There were no recorded instances of student cheating/hacking or attempting to do either. Invigilators and students were positive with the experience overall.

The following challenges were noted:

- ensuring sufficient battery life for the laptops (most venues are not equipped for large numbers of standalone desks with power points either in the floor or run along the ceiling);

- providing sufficient Wi-Fi connectivity;

- providing IT support for invigilators who did not feel confident fixing any technical issues (e.g. setting up and managing connections to the closed Wi-Fi access point);

- muting the audio on student laptops in order to minimise sound, although typing was not found to be any louder/more distracting than pen and paper.

The team who ran the OU computerised/online exams project has other higher priorities at the moment and the project is thus on hold. They plan to restart it as soon as possible, although they noted that they expect numerous blockers at scale, mostly regarding university infrastructure, changes to script handling and on-screen marking.

LONDON SCHOOL OF ECONOMICS (LSE), UK

The LSE conducted pilots of E-exams in two Law modules in 2014-15 (one undergraduate and one Master's level). Both were timed, take-home formative mock exams - the timed component was highly valued as an effective simulation of the final exam. Students used their own computers to type answers to essay questions.

The aim of the pilots was to explore students' perceptions of typing versus handwriting exams, and to consider the impact of introducing typed exams on the students and academic and academic support staff who were involved in the process. According to the team, "Overall, the pilots were successful in allowing academic and academic support staff at LSE to uncover a broad range of student views and preferences pertaining to typed exams while further providing an opportunity to test the ExamSoft software. The findings reveal a general willingness on the part of students to engage with typed exams but highlight the importance of having adequate training and support to facilitate any shift toward e-assessment practice. The pilots further illustrate the coordination and communication required with and amongst various stakeholders at LSE to ensure security, regulations and facilities can support the implementation of e-assessment Practice" (Chatzigavriil & Fernando, p. 5).

EDINBURGH BUSINESS SCHOOL (HERIOT-WATT), UK

The Business School offers a global distance learning MBA, with e-assessment offered in exam centres worldwide, in a secure, locked-down and invigilated environment. They launched e-assessment in 2016 — it is a gradual roll-out across the school, alongside traditional pen-and-paper exams at present. They run a total of 47 examinable courses, the majority of which are essay-based. They use the BTL Surpass platform which allows one to select the right question type and do the whole process onscreen — item authoring, test creating, test delivery and marking.

At the beginning of June 2017, they delivered exams in 68 exam centres, for 12 different subjects. "The ambition is for the majority of our exams to be delivered by e-assessment by December 2018 in 150 exam centres (possibly more) to 8000 students per exam session (exam sessions are four times a

year), offering pen and paper as an exception. We are looking at BYOD and remote invigilation as well" (Martha Gibson, posting to ALT-Members mailing list, 28 June 2017).

UNIVERSITY OF DUNDEE, UK

The Library and Learning Centre (LLC) at the University of Dundee offers and supports the use of ExamOnline (provided by Scottish company Intelligent Assessment Technologies). This system offers four apps via a web browser:

- Authoring app (create a new test or question bank or edit an existing one)
- Delivery app (open or schedule a test sessions, or manage an existing one)
- Results app (view, mark, moderate or output test results)
- System Settings app (for system administrators).

The initiative started in 2011, in response to growing demand from both departments and students for a secure system for typing answers to essay-style examinations online, using standard word processing functionality. Students had challenged the fairness of being asked to handwrite exams for two or more hours when they are used to typing in their everyday lives.

The team explored various technology options for the online delivery, recording and marking of short-answer and essay-based examinations, and ultimately decided to trial the ExamOnline assessment system developed by Scottish company Intelligent Assessment Technologies.[17] 'At the start of academic year 2011/12 a production licence was purchased and a carefully managed rollout implemented by the LLC initially involving two Schools — School of Computing and CEPMLP. This was subsequently extended in 2012/13 to include the School of Life Sciences (Learning & Teaching) and School of History' (Walker, n.d.).

The university's requirements were:

- Use a desktop solution as opposed to BYOD.
- Enable both on-screen marking and the option to distribute submissions to PDF for marking offline.
- Save candidates' answers to both the server and local hard disk to ensure redundancy in the event of either network or PC failure.

The findings reveal that students are happier typing answers for an hour or two, rather than handwriting. They can re-format their answers in a way that is not possible when handwriting. The software (ExamOnline) allows students to insert a hand-drawn diagram to support an answer; this is used quite extensively, although students need to learn how to follow the required steps in order to match their hand-drawn diagrams with their online answers. Academic staff enjoy the on-screen marking facility and the fact that they don't have to decipher handwriting (Yvonne Osler, Centre for Technology and Innovation in Learning (CTIL), University of Dundee, personal communication, 15 August 2017).

The team has not yet investigated BYOD for the known security and technical reasons, but it is something that they intend looking into in the near future.

BERGEN UNIVERSITY (UIB), NORWAY

The Faculty of Mathematics and Natural Sciences at UiB began implementing digital exams in spring 2015 and by spring 2016, 55% of all exams were digital. They have the goal of complete digitisation of all assessment processes by 2017; however, their 2016 report (University of Bergen, 2016)

---

[17] http://www.intelligentassessment.com/

acknowledges that this is unlikely to be achievable. Major barriers are the need for students to write mathematical/chemical formulae or draw diagrams; and students need to become more familiar with a range of digital tools that should be used during their coursework. The current solution is to have students submit paper attachments which are then scanned and added to the students' responses in Inspera. In some subjects, students will continue to write their exams with pen on paper, but their scripts will be scanned; all further administration and marking will be digital.

The UiB working group makes the strong point that:

> Thorough and long-term efforts on digitisation are required to ensure academically sound solutions, where the focus is on the coherent whole of the study programme and its subjects. Hasty and haphazard solutions that compromise academic quality, such as the exaggerated use of multiple-choice tasks, must be avoided (University of Bergen, 2016, p. 27).

UiB uses the Inspera Assessment platform. Although the system supports syntax for over 50 programming languages, it is not possible to compile or run computer code. Their exams consist primarily of multiple-choice, long answer and programming code questions; they also use the platform for submission of term papers and completion of home exams (both file uploading and answers typed directly in a browser).

AARHUS UNIVERSITY, DENMARK

The Aarhus University School of Business and Social Sciences (BSS) chose a 'big bang' implementation strategy by digitising all written exams in the 2014 summer exam period. They implemented the digital assessment system WISEflow across 7 departments with a total of 14,000 students. After the first three exam periods, 105,000 individual exams had been distributed and completed using WISEflow and about 90% of all written exams are now digitised across the business school.

The system handles both take-home assignments and on-site exams. In WISEflow, all parts of a written exam can be handled without the use of paper: creating and setting up the exam, conducting the exam, and assessing the responses, including notetaking, grading and archiving. Administrators, assessors (lecturers and examiners) and students are assigned different roles and rights in what are called 'exam flows'. To date, the implementation has not experienced any system crashes, and no exams have had to be cancelled or postponed due to technical errors.

APPENDIX B. METHODS OF EVALUATING E-EXAMS TRIALS

Table B.1 summarises the methods by which the reactions of students and staff to the experience of sitting and marking e-exams have been evaluated. The methods have been collected from peer-reviewed research articles and project reports reviewed for this report. The table is intended to provide input into the design of the evaluation of the e-exams trials in 2018. For this reason, it primarily includes articles and reports that have published at least one of their data collection instruments, either within the document itself or openly on the Web. In keeping with the purpose of this report, the table does not include the actual methods of research studies seeking to compare typed and handwritten exams.

Table B.1 Evaluation methods and links to data collection instruments

Reference:	Participant group:	Timing relative to the exam/test	Method	Questions asked	Access to instruments
Charman (2014)	Students	Before[18]	Questionnaire	Level of computer proficiency; reasons for choice of medium.	Questions paraphrased in article
		After	Focus group	Not described.	Not provided
Coniam (2011) Coniam (2012) Coniam & Yan (2016) Yan (2013)	Markers	Before	Questionnaire	Same questions in both (responses compared): e.g. computer proficiency; comfort reading on-screen; expectations; concerns; attitude	Questions paraphrased in Coniam (2012)
		After	Questionnaire		Appendix to Yan (2013)
			Semi-structured interviews	Volunteers from the questionnaire.	Questions paraphrased in Coniam (2011)
Hillier (2014)	Students	N/A	Questionnaire	Exploratory survey addressing all forms of digital assessment. Design of questions drew from, inter alia, Dermo (2009) and Hillier & Fluck (2013)	Questions listed in article
Hillier (2015)	Students	Before; during set-up/practice session	Questionnaire	Feedback on software and training	Selected questions listed in article
		After (immediately)	Questionnaire	Reasons for choice of medium; main differences typing *vs* handwriting; main concerns about e-exams	
Kohler (2015)	Students	After	3 questionnaires	Demographic data; experience of writing, both handwritten	Links to SurveyMonkey

---

[18] 'Before' and 'After' generally denote 'within a few days of the exam or test'. In a few cases, the evaluations were conducted immediately the students finished the exam or were delayed for a period of months, and these are indicated within the table.

Reference:	Participant group:	Timing relative to the exam/test	Method	Questions asked	Access to instruments
				and typed; comparison of the two media.	within article
			Keyboarding test	Speed (WPM); accuracy.	Test is publicly available; URL given in article
	Additional student	After	Interview with stimulated recall	Additional participant who had been video-recorded as he took the exam.	Not provided
	Markers	After	Questionnaire	Perceptions of marking handwritten vs typed scripts	Link to SurveyMonkey within article
Lee (2002)	Students	Before	Questionnaire	Demographic data; writing behaviour.	Appendix to article
		After	Interview	How they composed their essays (writing, revising); comparison between handwriting and computer. (Used questions from Bridwell, Brooke & Sirc, 1989.)	
Lee (2004)	Students	After	Questionnaire	Primarily a comparison between computer and handwriting modes; also asked students whether they felt they performed better on the computer test.	Appendix to article
Mogey et al. (2008)	Students	After	Focus group	Computer proficiency; experience of the exam; views on e-exams.	Questions paraphrased in article
Mogey, Cowan, Paterson & Purcell (2012)	Students	After (immediately)	Questionnaire	Process, physical effects, perceptions of outcome.	Questions listed in article
Mogey & Fluck (2015)	Students	After	Questionnaire	Demographic data; preference; comparison of experience of handwritten and typed exams in terms of process; normal preparation of coursework; self-assessment of typing speed (*vs* handwriting) and accuracy.	Appendix to article
Whithaus, Harrison & Midyette (2008)	Students	After (delayed)	Questionnaire	Reasons for choice of medium (typing vs handwriting); advantages and disadvantages of typing.	Not provided
	Markers	After	Structured interviews	Differences overall; advantages and disadvantages of each medium; any criteria stronger in one medium than the other; subjective impression whether scored typed exams higher, lower or the same; interest in on-screen marking; differences in essay quality.	Questions listed in article

GLOSSARY

This glossary has been adapted from Jisc (2010) and Jisc (2016). A generic definition is provided for most terms; Oxford-specific interpretations and definitions are indicated where appropriate.

Term	Definition
Adaptive test	A sequential test in which successive items are presented based on the properties and content of the items, and the participant's response to previous items.
Assessment criteria	What the candidate is expected to do during an assessment in order to demonstrate that a learning outcome has been achieved.
Assessor	The person who assesses a candidate's work (same as 'marker' or 'examiner')
Authentic assessment	An assessment that places candidates in a real-life or simulated scenario that requires them to apply appropriate knowledge and skills.
Author	The writer of an item or test. In an e-assessment context, this is the subject matter expert (SME) rather than the technologist who produces the question in its on-screen format.
Automated language analysis	An electronic process by which candidates' typed responses to essay-style questions are analysed and marked electronically.
Closed question type	A question in which the range of possible responses that the student can give is limited (for example a multiple choice question).
Constructed response question type (same as 'open-ended' question)	A type of question which requires a student to create a response themselves (e.g. typing an answer) rather than selecting an option (e.g. MCQ). Includes short answer and essay-style question types.
Digital assessment	Computers and software systems are used for the preparation and presentation of assessment activities, and to record and save student responses. Includes objective tests and open-ended question types.
E-assessment	(see 'digital assessment')
E-exams	(*Oxford-specific interpretation*) Timed examinations in which students type their responses on a computer in the physical presence of an invigilator (typically, in an exam hall or other room allocated for the purpose).
Electronic management of assessment (EMA)	The end-to-end electronic processes used to prepare, deliver and manage exams — from the perspective of institutions, administrators, tutors, markers and candidates.
Essay-style question type	A type of question where the student is expected to construct a prose response (more than a paragraph or two).
Formative assessment	Assessment that provides developmental feedback to a student about an assessment activity so that they can improve their learning and performance in future assessment activities. As such, it usually takes place during the learning programme (rather than at the end — summative; or beginning — diagnostic).
Free-text reading tool	Software that enables candidates' typed responses to essay-style questions to be analysed and marked electronically.
High-stakes	One in which the outcomes are of high importance to both the institution and to candidates and affect progression to another phase

Term	Definition
assessment/test	of the qualification.
Item bank/pool	A storage facility for items (questions) which allows them to be maintained and used for automatic and manual test generation purposes (to create tests on-paper and/or on-screen). Today, almost all item banks are electronic.
Locked-down desktop/browser	A locked desktop or browser is used in assessments where students must have no access to computing resources (e.g. other applications such as calculators, internet search engines, etc.) other than those provided with the test. The locked-down feature prevents students from accessing the operating system or desktop and other functions while the test is running.
Low-stakes assessment/test	One which is non-statutory and has little or no external impact on the institution or candidate; results are available locally.
Objective tests	Tests containing questions to which the response can be marked right or wrong without the need for expert human judgement. Most closed question types are objective; most constructive response questions are not objective.
Offline assessment/exam	An on-screen assessment which is conducted without using an internet connection during the test (although an internet connection may well be used to deliver the test to the client computer prior to the test starting, and to upload the candidate responses once the test has completed).
Online assessment/exam	An on-screen assessment which relies on an internet connection during the test to download subsequent questions and upload candidate responses. Sometimes referred to as 'conducting a test live over the internet'.
On-screen marking (OSM)	The marking of exam scripts in a digital medium using an appropriate tool. The scripts may have been typed, or they may be scanned copies of handwritten originals.
Open-ended question type (same as 'constructed response' question)	A task or question with no pre-determined process or outcome (e.g. an essay-type question).
Question and test interoperability (QTI)	Specification for tests and items which can be authored and delivered on multiple systems interchangeably — designed to facilitate interoperability between systems.
Randomised question selection	The random selection of questions from a predefined set; or altering the sequence in which questions are presented to different candidates.
Rich media	Dynamic content formats that can be included in presenting questions in an e-exam, such as video, animation, audio and interactive components, compared with static media such as pictures, diagrams, text.
Secure browser (see also 'Lock-down desktop')	A software package used to provide desktop security when delivering an assessment over the Internet. Commonly these products provide a variety of lock-down features which prevent the candidate from accessing other programs, such as the Internet, while undertaking an exam.

Term	Definition
Short answer question type	A question (usually in an objective test) which requires the candidate to provide a short textual answer (usually more than one letter and up to a sentence).
Summative assessment	An assessment generally undertaken at the end of a learning activity or programme of learning which is used to make a judgment on the candidate's overall achievement. A key purpose of summative assessment is to record, and often grade, the candidate's performance in relation to the stated learning objectives of the programme.

REFERENCES

Aspåker, H. (2016). The myth of the cheat proof digital exam. [Blog post]. Retrieved from https://medium.com/@haspaker/the-myth-of-the-cheat-proof-digital-exam-dcbafcf62613#.81in30u9x

Augustine-Adams, K., Hendrix, S.B., & Rasband, J.R. (2001). Pen or printer: Can students afford to handwrite their exams? *Journal of Legal Education, 51*, 118–129.

Bausili, A.V. (2017). From piloting e-submission to electronic management of assessment (EMA): Mapping grading journeys. *British Journal of Educational Technology*. https://doi.org/10.1111/bjet.12547

Bridgeman, B., & Cooper, P. (1998). *Comparability of scores on word-processed and handwritten essays on the Graduate Management Admissions Test*. Paper presented at the Annual Meeting of the American Educational Research Association, San Diego CA, 13-17 April, 1998.

Chatzigavriil, A., & Fernando, T. (2015). Law e-Assessment pilot study. Internal report: The London School of Economics and Political Science. Retrieved from http://lti.lse.ac.uk/wp-content/uploads/2016/08/Law-e-assessment-Pilot-study.pdf

Coniam, D. (2011). A qualitative examination of the attitudes of Liberal Studies markers towards onscreen marking in Hong Kong. *British Journal of Educational Technology, 42*(6), 1042–1054. http://dx.doi.org/10.1111/j.1467-8535.2010.01136.x

Coniam, D. (2013). The increasing acceptance of onscreen marking — the 'tablet computer' effect. *Educational Technology & Society, 16*(3), 119–129.

Coniam, D. (2016). A comparative picture of the ease of use and acceptance of onscreen marking by markers across subject areas. *British Journal of Educational Technology, 47*(6), 1151–1167. http://dx.doi.org/10.1111/bjet.12294

Connelly, V., Dockrell, J.E., & Barnett, J. (2005). The slow handwriting of undergraduate students constrains overall performance in exam essays. *Educational Psychology, 25*(1), 99–107. http://dx.doi.org/10.1080/0144341042000294912

Dawson, P. (2016). Five ways to hack and cheat with bring-your-own-device electronic examinations. *British Journal of Educational Technology, 47*(4), 592-600. https://doi.org/10.1111/bjet.12246

Dixon, F., Cassady, J., & Cross, T. (2005). Effects of technology on critical thinking and essay writing among gifted adolescents. *The Journal of Secondary Gifted Education, 16*(4), 180–189.

Falvey, P. & Coniam, D. (2010). A qualitative study of the response of raters towards onscreen and paper-based marking. *Melbourne Papers in Language Testing, 15*(1), 1–26.

Fluck, A., Pullen, D., & Harper, C. (2009). Case study of a computer based examination system. *Australasian Journal of Educational Technology, 25*(4), 509–523.

Graham, S., Weintraub, N., & Berninger, V.W. (1998). The relationship between handwriting style and speed and legibility, *The Journal of Educational Research, 91*(5), 290–297. http://dx.doi.org/10.1080/00220679809597556

Hillier, M., & Fluck, A. (2013). Arguing again for e-exams in high stakes examinations. In H. Carter, M. Gosper, & J. Hedberg (Eds.), *Electric dreams. Proceedings ascilite, Sydney 2013* (pp. 385–396).

Hillier, M. (2014). The very idea of e-Exams: student (pre)conceptions. In B. Hegarty, J. McDonald, & S.-K. Loke (Eds.), *Rhetoric and reality: Critical perspectives on educational technology. Proceedings ascilite, Dunedin 2014* (pp. 77–88).

Hillier, M. (2015a). E-exams with student owned devices: Student voices. *Proceedings of the International Mobile Learning Festival: Mobile learning, MOOCs and 21st century learning, May 22-23, 2014, Hong Kong SAR, China 2014* (pp. 582–608).

Hillier, M. (2015b). To type or handwrite: student's experience across six e-Exam trials. *Proceedings ascilite, 30 Nov-3 Dec, Perth 2015* (pp. 143–154).

Jensen, T. K. (2015). Implementation of digital assessment at Aarhus BSS. Aarhus Centre for Teaching and Learning. Retrieved from https://heconference.co.uk/wp-content/uploads/sites/8/2017/07/WISEflow-report-from-Aarhus-BSS.pdf

Jisc. (2007). *Effective practice with e-assessment. An overview of technologies, policies and practice in further and higher education*. Retrieved from https://www.jisc.ac.uk/media/documents/themes/elearning/effpraceassess.pdf

Jisc. (2010). *Effective assessment in a digital age. A guide to technology-enhanced learning and teaching*. Retrieved from https://www.jisc.ac.uk/media/documents/publications/effectivepracticedigitalage.pdf

Jisc. (2015). *Transforming assessment and feedback with technology*. Retrieved from https://www.jisc.ac.uk/guides/transforming-assessment-and-feedback

Jisc. (2016). *Requirements for E-exams systems*. Retrieved from http://repository.jisc.ac.uk/6314/1/EMA_System_Requirements_Template_published_08_Jan_2016.xlsx

Johnson, M., & Nádas, R. (2009). Marginalised behaviour: digital annotations, spatial encoding and the implications for reading comprehension. *Learning, Media and Technology, 34*(4), 323–336. http://dx.doi.org/10.1080/17439880903338606

Johnson, M., Nádas, R., & Shiell, H. (2009). *An investigation into marker reliability and some qualitative aspects of on-screen essay marking*. Paper presented at the British Educational Research Association Annual Conference, University of Manchester, 2-5 September 2009.

Johnson, M., Hopkin, R., Shiell, H., & Bell, J.F. (2012). Extended essay marking on screen: is examiner marking accuracy influenced by marking mode? *Educational Research and Evaluation, 18*(2), 107–124. http://dx.doi.org/10.1080/13803611.2012.659932

Jordan, S. (2013). E-assessment: Past, present and future. *New Directions for Institutional Research* (*NDIR), 9*(1), 87–106. http://dx.doi.org/10.11120/ndir.2013.00009

Kohler, B. (2015). Paper-based or computer-based essay writing: differences in performance and perception. *Linguistic Portfolios, 4*(1), Article 13, 129–146. Retrieved from: http://repository.stcloudstate.edu/stcloud_ling/vol4/iss1/13

Lee, Y-J. (2002). A comparison of composing processes and written products in timed-essay tests across paper-and-pencil and computer modes. *Assessing Writing, 8*, 135–157. http://dx.doi.org/10.1016/S1075-2935(03)00003-5

Lee, H.K. (2004). A comparative study of ESL writers' performance in a paper-based and a computer-delivered writing test. *Assessing Writing, 9*, 4–26. http://dx.doi.org/10.1016/j.asw.2004.01.001

Mogey, N., Sarab, G., Haywood, J., van Heyningen, S., Dewhurst, D., Hounsell, D., & Neilson, R. (2008). The end of handwriting? Using computers in traditional essay examinations. *Journal of Computer Assisted Learning, 24*, 39–46. http:/dx.doi.org/10.1111/j.1365-2729.2007.00243.x

Mogey, N., Paterson, J., Burk, J., & Purcell, M. (2010). Typing compared with handwriting for essay examinations at university: letting the students choose. *ALT-J, 18*(1) 29–47. http://dx.doi.org/10.1080/09687761003657580

Mogey, N. (2012a). Students' choices between typing and handwriting examinations. *Active Learning in Higher Education, 13*(2), 117–128. http://dx.doi.org/10.1177/1469787412441297

Mogey, N., & Paterson, J. (2013). Stylistic differences between typed and handwritten essay examinations. *International Journal of e-Assessment, 3*(1), 1–14.

Mogey, N., & Hartley, J. (2013). To write or to type? The effects of handwriting and word-processing on the written style of examination essays. *Innovations in Education and Teaching International, 50*(1), 85–93. http://dx.doi.org/10.1080/14703297.2012.748334

Mogey, N., & Fluck, A. (2015). Factors influencing student preference when comparing handwriting and typing for essay style examinations. *British Journal of Educational Technology, 46*(4), 793–802.

Noyes, J.M., & Garland, K.J. (2008). Computer- vs. paper-based tasks: Are they equivalent? *Ergonomics, 51*(9), 1352–1375. http://dx.doi.org/10.1080/00140130802170387

Peverly, S.T. (2006). The importance of handwriting speed in adult writing. *Developmental Neuropsychology, 29*(1), 197–216. http://dx.doi.org/10.1207/s15326942dn2901_10

Powers, D.E., Fowles, M.E., Farnum, M., & Ramsey, P. (1994). Will they think less of my handwritten essay if others word process theirs? Effects on essay scores of intermingling handwritten and word-processed essays. *Journal of Educational Measurement, 31*(3), 220–233. Retrieved from http://www.jstor.org/stable/1435267

Rytkön, A., & Myyry, L. (2014). Student experiences on taking electronic exams at the University of Helsinki. *Proceedings of the EdMedia World Conference on Educational Media and Technology 2014* (pp. 2114–2121).

Shaw, S. (2008). Essay marking on-screen: implications for assessment validity. *E-Learning, 5*(3), 256–274. http://dx.doi.org/10.2304/elea.2008.5.3.256

Shermis, M.D., & Lombard, D. (1998). Effects of computer-based test administrations on test anxiety and performance. *Computers in Human Behavior, 14*(1), 111–123.

Sindre, G., & Vegendla, A. (2015a). *E-exams and exam process improvement*. Paper presented at the Norwegian Informatics Conference (Norsk Informatikkonferanse — NIK) held in Ålesund, Norway 23-25 November 2015. Retrieved from https://www.researchgate.net/publication/299497855_E-exams_and_exam_process_improvement

Sindre, G., & Vegendla, A. (2015b). *E-exams versus paper exams: A comparative analysis of cheating-related security threats and countermeasures*. Paper presented at the Norwegian Information Security Conference (Norsk Informasjonssikkerhetskonferanse — NISK) held in Trondheim, Norway, 9-11 September 2015. Retrieved from https://www.researchgate.net/publication/299498076_E-exams_versus_paper_exams_A_comparative_analysis_of_cheating-related_security_threats_and_countermeasures

Sulzenbruck, S., Hegele, M., Rinkenauer, G., & Heuer, H. (2011). The death of handwriting: secondary effects of frequent computer use on basic motor skills. *Journal of Motor Behavior, 43*(3), 247–251. http://dx.doi.org/10.1080/00222895.2011.571727

Timmis, S., Broadfoot, P., Sutherland, R., & Oldfield, A. (2016). Rethinking assessment in a digital age: opportunities, challenges and risks. *British Educational Research Journal 42*(3), 454–476. http://dx.doi.org/10.1002/berj.3215

Tisi, J., Whitehouse, G., Maughan, S., & Burdett, N. (2013). *A review of literature on marketing reliability research. Report for the Office of Qualifications and Examinations Regulation (Ofqual)*. Slough: NFER.

Truell, A.D., Alexander, M.W., & Davis, R.E. (2004). Comparing postsecondary marketing student performance on computer-based and handwritten essay tests. *Journal of Career and Technical Education, 20*(2). No page numbers. Retrieved from https://ejournals.lib.vt.edu/JCTE/article/view/637/922

UCL (2011). *Exams on laptops — project review*. University College London.

University of Bergen (2016). Report from the Working Group for Digital Education and Assessment at the Faculty of Mathematics and Natural Sciences. Retrieved from https://mitt.uib.no/courses/2816/files/347048?module_item_id=27900

Walker, D. (n.d.). Essay-based exams online — transition, not transformation. e-Assessment Association (eAA). Retrieved from http://www.e-assessment.com/news/essay-based-exams-online-transition-not-transformation/

Walker, R., & Handley, Z. (2016). Designing for learner engagement with computer-based testing, *Research in Learning Technology, 24*(1), 30083. http://dx.doi.org/10.3402/rlt.v24.30083

Walker, R., Voce, J., Swift, E., Ahmed, J., Jenkins, M., & Vincent, P. (2016). *2016 survey of technology enhanced learning for higher education in the UK*. Report for the Universities and Colleges Information Systems Association (UCISA). Oxford: UCISA.

Whithaus, C., Harrison, S.B., & Midyette, J. (2008). Keyboarding compared with handwriting on a high-stakes writing assessment: Student choice of composing medium, raters' perceptions, and text quality. *Assessing Writing, 13*, 4–25.

Yan, Z., & Coniam, D. (2013) Assessing the ease of use in the environment and markers' acceptance of on screen marking: a Rasch measurement perspective. *Educational Research and Evaluation, 19*(5), 461–483. http://dx.doi.org/10.1080/13803611.2013.793604