SECURE E-EXAMINATION SYSTEMS COMPARED: CASE STUDIES FROM TWO COUNTRIES

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ABSTRACT

Aim/Purpose	Electronic examinations have some inherent problems. Students have expressed negative opinions about electronic examinations (e-examinations) due to a fear of, or unfamiliarity with, the technology of assessment, and a lack of knowledge about the methods of e-examinations.
Background	Electronic examinations are now a viable alternative method of assessing student learning. They provide freedom of choice, in terms of the location of the examination, and can provide immediate feedback; students and institutions can be assured of the integrity of knowledge testing. This in turn motivates students to strive for deeper learning and better results, in a higher quality and more rigorous educational process.
Methodology	This paper compares an e-examination system at FUT Minna Nigeria with one in Australia, at the University of Tasmania, using case study analysis. The functions supported, or inhibited, by each of the two e-examination systems, with different approaches to question types, cohort size, technology used, and security features, are compared.
Contribution	The researchers' aim is to assist stakeholders (including lecturers, invigilators, candidates, computer instructors, and server operators) to identify ways of improving the process. The relative convenience for students, administrators, and lecturer/assessors and the reliability and security of the two systems are considered. Challenges in conducting e-examinations in both countries are revealed by juxtaposing the systems. The authors propose ways of developing more effective e-examination systems.

Findings	The comparison of the two institutions in Nigeria and Australia shows e-examinations have been implemented for the purpose of selecting students for university courses, and for their assessment once enrolled. In Nigeria, there is widespread systemic adoption for university entrance merit selection. In Australia this has been limited to one subject in one state, rather than being adopted nationally. Within undergraduate courses, the Nigerian scenario is quite extensive; in Australia this adoption has been slower, but has penetrated a wide variety of disciplines.
Recommendations for Practitioners	Assessment integrity and equipment reliability were common issues across the two case studies, although the delivery of e-examinations is different in each country. As with any procedural process, a particular solution is only as good as its weakest attribute. Technical differences highlight the link between e-examination system approaches and pedagogical implications. It is clear that social, cultural, and environmental factors affect the success of e-examinations. For example, an interrupted electrical power supply and limited technical know-how are two of the challenges affecting the conduct of e-examinations in Nigeria. In Tasmania, the challenge with the "bring your own device" (BYOD) is to make the system operate on an increasing variety of user equipment, including tablets.
Recommendation for Researchers	The comparisons between the two universities indicate there will be a productive convergence of the approaches in future. One key proposal, which arose from the analysis of the existing e-examination systems in Nigeria and Australia, is to design a form of "live" operating system that is deployable over the Internet. This method would use public key cryptography for lecturers to encrypt their questions online.
Impact on Society	If institutions are to transition to e-examinations, one way of facilitating this move is by using computers to imitate other assessment techniques. However, higher order thinking is usually demonstrated through open-ended or creative tasks. In this respect the Australian system shows promise by providing the same full operating system and software application suite to all candidates, thereby supporting assessment of such creative higher order thinking. The two cases illustrate the potential tension between "online" or networked reticulation of questions and answers, as opposed to "offline" methods.
Future Research	A future design proposition is a web-based strategy for a virtual machine, which is launched into candidates' computers at the start of each e-examination. The new system is a form of BYOD externally booted e-examination (as in Australia) that is deployable over the Internet with encryption and decryption features using public key cryptography (Nigeria). This will allow lecturers to encrypt their questions and post them online while the questions are decrypted by the administrator or students are given the key. The system will support both objective and open-ended questions (possibly essays and creative design tasks). The authors believe this can re-define e-examinations as the "gold standard" of assessment.
Keywords	e-examination, e-Learning, public-private relationships, open-source software, accreditation authorities, post-paper assessment

INTRODUCTION

Electronic examinations (e-examinations) are now a viable alternative method of assessing student learning. They provide freedom of choice in terms of the location of the examination (whether examinations are running synchronously or asynchronously) and can provide immediate feedback. The broad aim is that students and institutions can be assured of the integrity of knowledge testing. This

in turn motivates students to strive for learning and better results in a higher quality and more rigorous educational process.

E-examinations still have some inherent problems: students may have negative opinions about e-examinations due to a fear of or unfamiliarity with the technology and a lack of knowledge about the methods of e-examinations. In this research, the authors compared e-examinations in Nigeria with those of Australia, with the aim of identifying the challenges and to propose strategies for improvement.

Examination is a perennial focus of debate (Baird, Cresswell, & Newton, 2000). Qualifications authorities balance examinations with coursework assessment (Elwood, 1999). In this paper, the authors do not question the value or validity of examination-style assessment, which debate is the province of qualifications authorities and often reflects the particular syllabus or subject content. Rather, the authors examine e-examinations in the light of information technology developments and explain the anticipated clash between fully online and live operating system styles of e-examination. The authors' interest in e-examinations stems from their role in spearheading computer-based assessment at their respective institutions. The viewpoints are complementary, yet also offer an unusual and more holistic perspective.

"E-examinations" refers to the use of computers by candidates in a high-stakes supervised (proctored) assessment, generally simultaneously in a fixed time period. Adebayo and Abdulhamid's survey (2010) shows this definition has been widely accepted in private and public institutions of higher learning as well as in high schools by identifying common practices. Adebayo and Abdulhamid's survey indicates several examination bodies in Nigeria preferred e-examinations to manual examinations (in which students use "pen on paper"). Staff and students preferred e-examinations because of their flexibility, security, integrity, and ease of use.

As with manual examinations, e-examinations require stakeholder co-operation and reliable equipment for success. The lecturers, invigilators, candidates, computer instructors, and server operators are the stakeholders in the conduct of e-examinations. However, unlike manual examinations, where the stakeholders can (with opportunity) influence the integrity of the results, the integrity of e-examinations' results depends on the security apparatus and technology appropriateness. For example, closed circuit television can be used to monitor candidates during the conduct of e-examinations rather than the use of invigilators alone in manual examinations. The results of e-examinations are submitted directly to the central server for onward processing and delivery. This compares with manual examination results, which can be modified by the tutor.

There are many examples of computers being employed in learning and many other types of assessment methods. The problems of teaching large classes (Kumar, 2011) are being overcome by the use of learning content management systems for delivering materials over the Internet and educating geographically dispersed students. These students are becoming accustomed to using a computer for all learning activities. Assessing this learning by using pen on paper examinations can therefore appear incongruous to these students; but it is frequently employed. This discord is one of the key reasons the authors have championed e-examinations, and which has stimulated our interest in their development beyond our own countries.

In this research the authors undertook a review of relevant literature – a notably large body of work, given the international interest in the deployment of computer technology in many facets of teaching and learning. Following this, a comparative analysis was undertaken using the authors' home teaching environments in order to expose challenges to their existing systems. Once these challenges and those identified in the literature review were understood, several strategies for overcoming strategies were proposed. Any institution considering implementing e-examinations as an assessment method could employ these strategies. With the rapidly growing deployment of computers and associated technology in developing nations, these strategies are timely.

LITERATURE REVIEW

To establish the context of e-examinations, literature related to the growth of e-Learning and e-assessment was investigated. We located literature related to the following themes: e-Learning, e-assessment, and e-examinations.

There has been a surge of interest over the past five years in online assessment associated with national testing programs. For example, Australia's national testing program in schools will transition to an online format by 2019 (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2017).

The US Department of Education issued a request for information about Assessment Technology Standards for national online testing on December 20, 2010 (Twing, 2010). This request defined the range of technical issues (such as compatibility standards) required for widespread adoption of any new high-stakes assessment technology. Potential suppliers identified concerns about network access of any kind and the anticipated reliability of the computer equipment.

In 2014, the Australian state of Victoria's Department of Education and Early Childhood Development (DEECD) released a similar information request and tender for a reporting and analytics component of the online integrated assessment platform known as the Insight Platform. The advantages of putting such monitoring and diagnostic testing online include scalability, easy revision, centralised control over access, and swift marking of many items. The disadvantages are the need for constantly reliable equipment (including communication links), the restrictions of posing questions within a web browser, and the cost of creating question items.

Offline assessment methods are growing more slowly in comparison. The main thrusts have been to capitalise on BYOD ("bring your own device") strategies by using "live" operating systems. A "live" operating system can be put onto a removable storage device, such as a CD-ROM or USB drive. The BYOD computer boots from this device and while the computer remains activated, it is totally under the control of this operating system. Thus, assessors can devise highly complex activities (with the option of involving the use of additional software applications) beyond the scope of a web page in a secure environment, which is identical for every candidate. Finland stands out in publishing a commitment to move all high-stakes school examinations to such a system in its Digabi project (Matriculation Examination Board of Finland [MEB], 2013). The project commenced operation in 2016 with the computerisation of university entrance examinations in three subjects and will convert all such examinations to computers by 2019.

Importantly, BYOD strategies provide institutions with access to individual student computing equipment without incurring prohibitive costs. Plan Ceibal in Uruguay is an example of a national "one laptop per child" program, which was funded by the central government. This was partially replicated in Australia by the Digital Education Revolution (Crook & Sharma, 2013). Ricci (2015) identifies the 2013 closure of the previous federal government's Digital Education Revolution (DER), which had provided laptop computers to students from Year 9 level onward, as the critical catalyst for a new strategy. For many Australian schools, BYOD has become that alternative strategy. A national survey (conducted by educational software provider Softlink) of 1267 schools across Australia in 2014 revealed that BYOD programs grew by 30 per cent in that year alone. Numerous primary schools have also embarked on BYOD schemes with the introduction of iPads: "despite lingering concerns about network capability, affordability and e-safety, some describe the BYOD global trend as the next stage in the evolution of schooling: one that will provide students with the skills they will require for life in the technological age" (Ricci, 2015).

The concept of BYOD, whereby students sit an in-person exam under invigilated conditions (or in a specific location) with their own laptop, requires specific software that restricts students accessing prohibited computer functions and files. This software and its security settings functions also provide access to any resources or software the examiner approves; or conversely, limit access when appro-

priate. Predictably, Dawson (2016) identifies the potential to cheat in BYOD exams: "the consequences of these hacks are significant, ranging from removal of the exam paper from the venue through to receiving live assistance from an outside expert".

In *BYOD in Education: A report for Australia and New Zealand*, Sweeney (2012) details the observations and findings from in-depth interviews and executive roundtable focus groups conducted by Intelligent Business Research Services. Sweeney notes that "... it became evident that the more significant issue was not the 'device' per se but the delivery of software and services that impact educational activities" (p. 5), and concludes:

> *Everyone is looking for the 'One Approach' that alleviates all of the headaches of providing digital education (changing policies, duty of care, maintenance, etc.) while consuming as little of the scarce ICT budget as possible. In truth, there is not one approach that fits all educational institutions – or even a single approach that can be used across a single school* (p. 27).

A recent pilot study of an e-examination system at Central Queensland University (Wibowo, Grandhi, Chugh, & Sawir, 2016) found that students and staff,

> *… expressed a variety of feedback and concerns ...* [and] *the ineffectiveness of the existing system and other issues associated with the system could be improved. Future selection of e-exams system should consider features missing in current e-exams system. The implementation of e-exams is still in its infancy at CQUniversity, more work need* [sic] *to be done which requires collaboration among students, teaching, professional and technical staff, and decision makers at the institution* (p. 29).

Although our study specifically investigates and compares e-examinations in Australia and Africa, it is of value to understand a more global approach to this method of assessment and learning. There have been many commercial education options (outside the accredited tertiary sector), which have been operating in the field for nearly twenty years. For example, one company promotes itself as,

> *… a leading developer of online platforms for high-stakes assessment. Utilising the latest cloud-hosting technologies,* [and specialising] *in providing innovative, highly scalable and secure applications built to meet the assessment requirements of our clients now and for the future. Our team consists of highly experienced professionals who have been building online assessment systems together for a number of years and have delivered on a range of highly successful assessments in Australia, Europe, the US and Asia* (Janison, 2016).

In this case, it is worthy to consider the application of cloud-hosting technologies and how they will come into play, in terms of security, in the next five to ten years of e-examinations. Other international research investigates e-examination security and encryption (Sabbah, Saroit & Kotb, 2011), Moodle and e-Learning systems (Kumar, Gankotiya & Dutta, 2011), and connections between authoring tools, learning management, e-Learning and e-examinations (Impedovo, Lucchese & Pirlo, 2006). E-examinations have been deployed widely in Austria (Frankl, Schartner & Zebedin, 2012). An open source secure exam browser from Switzerland has been popular in a large number of institutions (Halbherr, Reuter, Schneider, Schlienger, & Piendl, 2014).

In 2012 students at Impington Village College in England were provided with iPads and Kindles loaded with the test papers by the University of Cambridge International Examinations board for a mock IGCSE biology exam, although students still handwrote their answers. The majority favoured the use of technology, but 33% of the students preferred pen on paper (McPherson, 2012; Ward, 2012). This was an early trial of one-to-one personal computer assessment technologies in secondary schools.

Technology has been used for high-stakes examinations in the authors' respective universities. By "high-stakes" we mean summative terminal assessments required to complete an element of a degree course. Fluck (2010) reported the different technical methods and some security methods were compared by Bjørklund (2010). The majority of law schools in the USA have adopted or investigated computer-based approaches to essay-style examinations (for example, learn.examsoft.com). Initial reports from Heidelberg indicate there are no systematic differences in achievement levels if candi-

dates have a free choice of writing tool when answering an examination (Hochlehnert, Brass, Moeltner, & Juenger, 2011). Studies from Edinburgh suggest computer-using candidates have a slight advantage, with more complex language and higher word-counts observed (Mogey & Fluck, 2015; Mogey & Paterson, 2012).

In terms of e-Learning, for example, MOOCs (Massive Online Open Courses - courses made available over the Internet, free of charge, to a very large number of people) have become globally popular (Kay, Reimann, Diebold, & Kummerfeld, 2013). Haynie (2014) notes MOOCs are "praised for providing a free education to people across the world. … But they have a murky record in terms of their overall effectiveness, particularly in light of their low student completion rates". Further, Fiona Hollands, who recently led a study on MOOCs for Columbia University's Teachers' College, acknowledges that "there is little data about whether MOOCs are more effective than other learning models. Almost no one is doing that work … It's rare and I don't really understand why people are avoiding it" (Haynie, 2014).

Tensions have emerged between the desire to improve the authenticity of assessment, yet retain the integrity of testing individuals for award purposes (Hillier & Fluck, 2015). These tensions extend to the various technologies becoming available for e-examinations. Wholly online methods contend with secured word-processing applications for legal and medical assessments (Alfredsson, Sejersen, Stathakarou, & Zary, 2015; Chatzigavriil & Fernando, 2015; Poutre, Hedlund, & Nau, 2015). These studies have reported differences in candidate acceptance and perceptions of assessment validity. However, at the institutional level, there is no clear roadmap for e-examination adoption without reputational risk.

The use of computers for examinations has been considered at the highest level by the authors' universities. The Federal University of Technology, Minna in Nigeria (FUT Minna) approved the use of online computers in examinations in February 2010. The University of Tasmania (UTAS) Academic Senate approved the use of offline e-examinations (in all disciplines) on 4 March 2011. Each university considered equity, technical reliability and implementation processes. The authors located only a few previous studies, which have compared e-examinations between geographical locations (Bukie, 2014; Spanaka & Kameas, 2013).

RESEARCH METHODOLOGY AND METHOD

Yin (1984) defines case study research method as an empirical inquiry that investigates a contemporary phenomenon within its real-life context and in which multiple sources of evidence are used (p. 23). A qualitative case study is "an approach to research that facilitates exploration of a phenomenon within its context using a variety of data sources" (Baxter & Jack, 2008, p. 544) and this ensures the issue is "not explored through one lens, but rather a variety of lenses which allows for multiple facets of the phenomenon to be revealed and understood" (Baxter & Jack, 2008, p. 545). This is based on the constructivist paradigm that truth is relative and is dependent on one's perspective; it acknowledges the importance of the subjective human creation of meaning but does not reject notions of objectivity.

According to Yin (2003), a case study design should be considered when the focus of the study is to answer "how" and "why" questions or when the researcher cannot (or should not) manipulate the behaviour of those involved in the study. A case study is an in-depth study of a particular situation. In this study the research was conducted at the institutional level in order to make cross-institutional comparisons. Our data were collected independently from the individual sites, and then organised into high-level categories for presentation and subsequent analysis. The researchers did not know the personal details of the individual e-examination candidates, when data were collected.

Bias (in the situation of limited samples) and selection bias are the obvious issues of validity in using a case study approach (Dion, 2005). This potential bias represents a limitation of this study. However, the two cases represent markedly different populations, education systems, and political contexts.

Therefore, selection bias is considered minimal as the cases exemplify such distinct differences. Participants were chosen through opportunistic sampling; that is, the cohorts observed were randomly selected according to their availability to the researchers. In drawing participants from diverse contexts, the results are expected to show if, and how, e-examinations can play a part in selecting students for university courses, and for their assessment once they are enrolled in a degree program. Furthermore, through comparative analysis of the two institutional cases, inspiration will be drawn for improved technologies and processes for e-examinations.

This research was undertaken subsequent to a visit to FUT Minna by one of the authors. It uses a qualitative comparative case study design and was conducted at the institutional level. Sample selection was by opportunity, since one author had become aware of the work at FUT Minna on the basis of searches using the "e-examination" term and arranged to visit the campus. It is not intended that these case studies should have similarities; in fact, the intentions and technologies at the two sites are very diverse, and therefore give a greater perspective on the subsequent issues than a closer match might have revealed. The two case studies are provided in the following section to preserve them as holistic descriptions. The case from FUT Minna is presented first, followed by the case from the University of Tasmania.

Using the *constant comparative analysis method* (Fram, 2013), each case study is arranged in four parts, with a general introduction that defines the technological approach and educational context. Glaser and Strauss (1967), the key proponents of grounded theory, describe the *constant comparative analysis method* as identifying a phenomenon, object, event or setting of interest; identifying a few local concepts, principles, structural or process features of the experience or phenomenon of interest; making decisions regarding initial collection of data based on one's initial understanding of the phenomenon (in that further data collection cannot be planned in advance of analysis and the emergence of theory); and engaging in theoretical sampling (pp. 28-52).

The goal of this approach (as a form of grounded theory) is to generate theories that explain how some, clearly identified, aspect of the social world "works." The key rationale for selecting comparison groups in the first phase is their theoretical relevance for fostering the development of emergent categories. Accordingly, in the second phase, computer use in university entrance selection processes is described. Third, the use of computer-based assessment in university courses, and finally, future directions are explored. After the cases are presented, the comparative analysis is described, and theories are proposed.

CASE STUDY ONE: FUT MINNA (NIGERIA)

BACKGROUND AND TECHNOLOGY

e-Learning and e-examination innovations in African countries are generally still at a low level, and this has led to limited utilisation of information technology facilities to enhance the conduct and development of examination systems. Further, the few countries in the forefront of the awareness and usage of e-examinations are facing challenges that range from poor electricity supply to facility maintenance. A report by Michigan State University, which focuses on e-Learning in Secondary School Education in Tanzania (Olsen et al., 2011) states:

> *Improving secondary education in Africa and other developing countries had until recently been overshadowed by programs focusing on national economic and infrastructure development. … Many new policies and projects have begun to introduce information and communications technologies and related teaching approaches, known collectively as electronic or e-learning, into schools ... e-Learning programs in Africa and in other developing countries are still often small, experiential pilot projects with little documented history of their successes and impacts. Nevertheless, a body of literature is emerging that analyzes e-learning programs* (p. iii).

In Nigeria, however, nearly all organisations, government ministries, and parastatals (business enterprises owned or controlled wholly or partly by the government) are now adopting e-examinations,

otherwise called online examinations, for high-stakes assessments, career evaluation, and aptitude tests (Osang, 2012). The parastatal organisations using pre-employment online assessments include the National Information Technology Development Agency and the Petroleum Technology Development Fund.

FUT Minna has been administering e-examinations since 2010. The University was one of the very first in Nigeria to adopt the electronic-based test and has overcome some major challenges, such as the security of the questions and also the integrity of the results produced using the electronic test. This led to early researchers proposing a more secure system (Adebayo & Abdulhamid, 2010).

The current e-examination process in FUT Minna is administered by the electronic Testing Company (eTC). The e-examination venue is a purposely-constructed building containing a campus server and an independent backup electricity supply linked to 120 thin client ("dumb") terminals, which issue multiple choice questions over an internal wired network. The student terminals do no processing, but transfer keystrokes to the server and display the server response on the screen. Questions from individual course lecturers are encrypted using his or her public RSA key (Rivest, Shamir, & Adleman, 1978) and sent directly to the eTC database pool from where they are uploaded onto the thin client terminals for candidates to answer. This e-examination security strengthens the reliability and efficiency of the system. Collusion and cheating is prevented within the dedicated building by the use of partitioned carrels and a video-surveillance system covering all candidates (Figure 1). Student identity is authenticated conventionally upon entry by using photo ID cards.

Figure 1: Candidate Workstation at FUT Minna.

UNIVERSITY ADMISSION SECTOR – NIGERIA

The national university admission authority, JAMB (Joint Admission and Matriculation Board) has commenced using examinations through electronic means. The eTC e-examination system at FUT Minna is used for the administration of the Post University Tertiary Matriculation Examination

(PUTME). Candidates from the surrounding area come to the eTC building for three to six days each year to sit the test. Afterwards, the PUTME candidates receive a scratch-off identity ticket. This provides each candidate with a unique number, which they can use to access the result system from an Internet café just two hours later to receive their marks.

E-EXAMINATIONS IN NIGERIAN UNIVERSITY COURSES

The eTC e-examination system is very efficient and effective for the various examinations usually conducted by FUT Minna. These range from internal course-work tests to examinations for most first year undergraduate students. This represents very wide adoption of the eTC e-examination system. Two of the sample e-examination multiple-choice questions are provided in Figure 2.

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1) Cryptanalysis is a term used to describe
A.   encryption
B.   decryption with the knowledge of encryption scheme
C.   decryption without the knowledge of encryption scheme
D.   none of the mentioned

2) In cryptography, which one of the following schemes is not a cryptosystem?
A.   Shift cipher
B.   Hill cipher
C.   Substitution
D.   electronic code book algorithm

Figure 2: Examples of multiple-choice questions from FUT Minna.

THE FUTURE OF ONLINE EXAMINATIONS IN NIGERIA

The future trajectory is for e-examinations to be deployed on a BYOD basis administered at a distance and at a convenient time for each candidate. This will be highly welcomed by distance learning students who can rarely attend lectures. It will bring many advantages to the conduct of examinations, as students will spend less time and money on transportation and avoid the risk of accidents and the likelihood of missing examinations in a country where distances are great and reliable transport is difficult to find.

Moreover, as JAMB has started conducting online e-examinations, many other examination bodies are expected to shortly follow this lead. The authors also expect to see many university examination administrating bodies conducting examinations online. This will assist in reducing processing time, reducing alteration cases (where test results are contested), and increasing student confidence in the assessment process. The authors also identified security from examination office staff as an important factor that must be given adequate priority to ensure the integrity of results.

CASE STUDY TWO: UNIVERSITY OF TASMANIA (UTAS, AUSTRALIA)

BACKGROUND AND TECHNOLOGY

Bachelor of Education (UTAS) undergraduates first sat an e-examination in an information technology subject at the University of Tasmania with institutional computers in 2007. Laboratory computers were booted from CD-ROMs containing a modified "live" Ubuntu operating system (a Linux distribution) called the eExam System. This operating system does not run from the internal hard disk of the computer, but relies solely on the external disk drive data. It does not change or use the internal disk drive. The e-examination ran in shifts to cope with the large number of candidates.

In successive years, the "live" operating system was modified to run from a USB thumb drive instead of a CD-ROM and to include anti-collusion features. There were two strategies behind this innovation. First, the aim was to create a sustainable base for BYOD equipment, as each student provides his or her own computer for any e-examination. Second, every candidate was provided with the iden-

tical application software suite and operating system to ensure equality of opportunity. This use of a "live" operating system overcomes the limitations of e-examinations delivered within a web page, such as those linking to a learning content management quiz system. Web page based e-examinations generally restrict students to choosing between answer options and inhibit the use of sophisticated software to demonstrate higher order thinking. The "live" operating system allows every student to run application software and could potentially permit the use of powerful speech recognition systems (Audhkhasi, 2009).

By 2013 over 1000 candidates had successfully used the system in high-stakes assessments. In 2014, Version 5 was developed from Ubuntu 12.04 at the University of Queensland. This could boot both Windows PC and Macintosh computers from the same USB data stick (www.transformingexams.com). This version also includes a copy of the Moodle learning content management system for handling multiple-choice and similar question types. Three key security measures were incorporated to prevent cheating (Kumar, 2012) and to provide a fair assessment context by:

- disabling communications to prevent Internet access or collusion;
- preventing access to local hard drives or other USB storage devices; and
- providing a unique visual image (for example, a pet animal) on all candidate screens at startup, for non-technical invigilators (exam supervisors without computer skills) to check technical compliance.

E-examination candidates can access a sample USB stick at least three weeks prior to their assessment to become familiar with the start-up process and operational characteristics. When commencing an e-examination, the candidate enters the assessment centre with their own computer and finds a USB stick on their designated desk with launching instructions. After starting their computer, each candidate's desktop security image is checked by supervisors before they are permitted to open the question paper and start writing answers. Periodically throughout, and at the end of the e-examination, their answers are saved on the USB stick, which is left on the desk after the assessment for collection, collation, and forwarding to assessors for marking.

UNIVERSITY ADMISSION SECTOR IN TASMANIA

The eExam System software was trialed by the Tasmanian Qualifications Authority (TQA) in 2011. TQA is responsible for the calculation of a national ranking for all students aspiring to enter university and the administration of subject-specific pre-tertiary examinations. A report on the 2011 trial states:

> *The e-exam in Information Technology & Systems was taken by 93 students at 10 exam centres. Each school had used e-exam* [sic] *for their mid-year examinations and was familiar with the system. There were no issues with major equipment failure* (Tasmanian Qualifications Authority [TQA], 2012).

In 2012 a "post-paper" question was trialed by the TQA, whereby no Internet connection was allowed or available. The question directs candidates to a small website provided on the USB drive containing rich features such as color images and animations (Figure 3). These could not have been easily provided on paper, hence the term "post-paper question".

The TQA's adoption of the eExam System was undertaken with no assistance provided by the designers after the initial handing over of the code and technical documentation. This was essentially a positive demonstration of innovation adoption as the receiving institution took ownership of the technology. Of interest was the implemented definition of equity: all students in the subject using the eExam System were obliged to use a computer. This ensured fairness for all candidates, and eliminated any bias due to differing text entry modalities.

The 'Up and Comers' Tennis Club is a medium-size tennis club with about 150 members. During the consultation process two particular problems were identified:
(i) The tennis club's web site is somewhat limited.
(ii) The tennis club's membership records are a mix of:
• some details written on membership forms
• some e-mails received and sent
• some records in a spreadsheet — mainly of those who had paid.
At the time, this was some of the tennis club's web site (click to see it). Specifically referring to this club's web site, discuss three aspects of it you would change and why.

Type your answer below this line:

Figure 3: Example of a post-paper question from a university admission e-examination.

E-EXAMINATIONS IN UNIVERSITY OF TASMANIA COURSES

Several UTAS disciplines trained faculty staff and either offered this mode to students as an option, or made it compulsory for assessment. An e-examination is generally conducted in the same venue as pen on paper exams and alongside them. Collusion is prevented by the layout of the desks, making it virtually impossible for a student sitting the examination to see the screen of any other candidate. Further, the e-examination technology prevents access to internal/external data storage devices and to all communication channels. Candidates' identities are validated using photo ID cards, as is standard operational procedure for university examinations. History, law, education, and medicine students have used the eExam System software at all year levels, thereby illustrating the diversity of subjects in which it can be applied. Lecturers in law, for example, commented the answer-scripts were much easier to read and mark.

These e-examinations can be divided into paper-replacement and post-paper assessments. In the case of paper-replacement e-examinations, candidates can choose to create text with a pen or with a keyboard. They are offered a choice of text creation methods, and all candidates answer the same questions. In this context, equity is assured by permitting each candidate to select his or her preferred writing implement (pen or keyboard). An example of a paper-replacement question used in the Faculty of Law is provided in Figure 4.

In 2011, Alpha Corp was fined $5,000,000 by the Federal Housing Court for collusive pricing under the House Prices Act, 2009 (Cth). It did not appeal the decision to the High Court….
Provide arguments for the Commonwealth government, including arguments that the High Court should be invited to reconsider the basis of constitutional review.

Please type your answer below this line

**Figure 4: Example of a paper-replacement question
from the Bachelor of Laws e-examination.**

Post-paper assessment incorporates additional media, such as video, or require the use of application software to solve problems. These media and software tools cannot be provided on paper. For example, a video of classroom practice was provided in a mathematics education examination where candidates had to critique the teaching pedagogy. For such post-paper e-examinations it is vital every candidate has access to a computer. From 2012 onwards candidates at UTAS were required to provide their own computer, but the university continued to provide some reserve equipment to cope with any reliability problems. These efforts enable new kinds of questions to be asked (see Figure 5 where computer aided design tools are expected to be used).
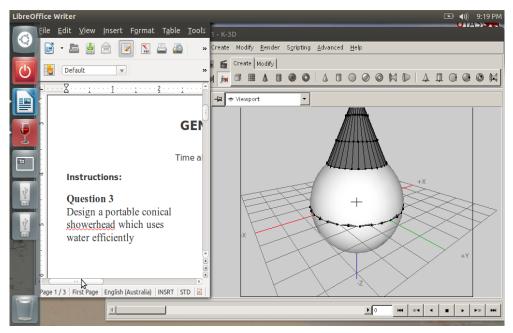
Figure 5: Example post-paper question (requires software use during e-examination).

FUTURE TRAJECTORY IN AUSTRALIA

Over the next five to ten years, e-examinations will be developed to the point that examination candidates will require minimal technical expertise. Some of the challenges now include the move to new start-up computer architectures (from Basic Input-Output System to Unified Extensible Firmware Interface), as Windows 8 and 10 are deployed. Greater numbers of ARM processors (replacing the Intel models) may need to be accommodated by e-examination systems. The popularity of tablets is under consideration, as these devices do not provide ways of booting from an alternative operating system source. They are also arguably poor devices upon which to input text at high speed, which is typical of e-examination conditions. By providing a rich e-examination environment supporting post-paper assessment, curricula can be transformed, taking advantage of the sophisticated software tools, which can also be used in exams. This will better match professional practice where such software tools are commonplace.

COMPARATIVE ANALYSIS

Comparative analysis was conducted by considering two different data dimensions. The first data dimension for comparison looked at the four parts of each institutional case study. The second data dimension for comparison considered the deeper technical features of the two e-examination systems used. These two dimensions of comparison elicited several key points for the discussion that follows.

Comparison of the four parts of the case studies showed the background and technologies are very different. FUT Minna serves a city with a population of 304,000 while the University of Tasmania is the only university in a small state of 517,000, at the time of writing. In Minna, the technology rolls out questions for up to 500 students *per* sitting, very readily; however, a failure in the server would affect all candidates. The question types are quite restricted (generally multiple-choice formats) and are marked automatically. Further, the purpose-built venue at FUT Minna provides ideal conditions for assessment. Conversely, in Tasmania there is an up-front administrative task of copying USB drives; however, this ensures the resilience of the assessment as any technical failure is restricted to just a single candidate. At the latter, question types are much wider, with every candidate having ac-

cess to the same full operating system. The Tasmanian examination environment is variably scalable in that extant (non-specialist) venues are employed.

Both institutions have used their technologies in the University admissions sector. The Nigerian case is particularly functional, in that it provides aspiring university students access to their results within hours. The Tasmanian case illustrates the use of post-paper assessment e-examinations in both the university admissions sector and in university courses. In FUT Minna degree courses the e-examination system is proving more suitable for first year course assessments where knowledge recall is a basic requirement. The UTAS example demonstrates application across year levels and disciplines, with a transition pathway from paper-replacement e-examinations to post-paper assessment. The future in FUT Minna is a move towards BYOD equipment and external assessment facilitated by enhanced security measures, using biometrics, for example. The challenges in Tasmania are to support a wider range of user devices and to promote curriculum change.

Overall, this first data dimension comparison showed the two institutions had different strategic objectives and had chosen e-examination systems to suit their respective purposes. Each system had strengths and weaknesses. Some of these strengths and weaknesses are likely to affect future development. The second dimension of comparison looked at the technical elements of each e-examination system in greater detail. Table 1 summarises the four main features of the two systems.

Table 1. E-examination features of the two Case Studies

E-examination Feature	FUT Minna, Nigeria	University of Tasmania, Australia
Types of questions	Objective questions only.	Both essay and objective questions, and full use of the Ubuntu operating system, within security constraints.
Cohort size at a sitting	A maximum of about 500 students can sit for the exams at a time.	The largest cohort assessed has comprised 120 candidates in a single hall and on another occasion, 150 candidates spread across multiple testing sites, including overseas locations (simultaneously).
Technologies used	Administered within a LAN or intranet environment. A server and a student information database are connected to the LAN. A question bank in the database was also connected to the Intranet.	Candidates' individual computers boot from USB sticks. Ubuntu 12.04 with a design specification, which allows both Windows PCs and Macintosh computers to boot from the same USB data stick. Questions come from individual lecturers, and can be either paper-replacement or post-paper in design.
Security Features	Username and passwords for both students and administrative login. Cryptographic techniques secure the database.	USB operating system disables communications to prevent Internet access or collusion. Interdicts access to local hard drives or other USB data sources. Provides a unique visual image (for example, a pet animal) on all candidate screens at start up, for non-technical invigilators to check compliance.

The differences in features and underlying technologies between the two cases provide a means of determining what might be desirable in any successive system and in anticipation of likely technological and educational developments. It would clearly be advantageous for any new system to deal efficiently with objective questions, as well as more subjective open-ended questions. The capacity to deal with ever growing cohort sizes and with a greater geographic distribution would also be beneficial to remote students. The setting of e-examinations can be enhanced by the use of question banks; however, faculty staff would require additional training for the specialisation of writing post-paper items. For e-examinations to have academic integrity, security will need to be absolutely ensured. In combination, these attributes provide starting points to develop and improve e-examination systems and processes for the future.

DISCUSSION

This paper demonstrates how e-examinations can play an active and useful role in selecting students for university courses and for their assessment once enrolled. The comparison of two institutions in Nigeria and Australia shows e-examinations have been implemented for these purposes. In Nigeria, there is widespread systemic adoption for university entrance merit selection; but in Australia this has been limited to one subject in one state, rather than being adopted nationally. Within undergraduate courses, the Nigerian scenario appears to be quite extensive in one university (all first year courses), while in Australia this adoption has been slower but has penetrated a wide variety of disciplines. A reading of the cross-case comparison, allows five observations to be made.

First, the integrity of the assessment and equipment reliability were common issues across the two case studies, although the delivery of e-examinations is different in each country. The Nigerian example uses an internal network to link institutional workstations in a dedicated building, while the Tasmanian approach is to boot student's own computers in the context of a mainstream conventional examination hall. Other technical solutions are available with a variety of commercial (for example, learn.examsoft.com; www.exam4.com) and open-source (for example, MEB, 2013) offerings.

These e-examination solutions have different strengths and weaknesses. As with any procedural process, any particular solution is only as good as its weakest attribute. If any element of the examination preparation, delivery, and answer script collection process breaks down, there is the chance of candidates not receiving the mark to which they are entitled. Inevitably comparisons are made with conventional paper examinations where failures are limited to one or two in a thousand. Any technical failure in an e-examination system becomes a threat to the integrity of the assessment.

Second, technical differences highlight the link between e-examination system approaches and pedagogical implications. In the Nigerian case, candidates must select from a list of prepared answers to each question. This allows automatic marking and provides an extremely fast turn-around time for assessment results but is largely limited to knowledge recall questions unless assessors are highly trained. The Australian technology supports essays (conventionally and tediously marked by human assessors) and sophisticated software use within a simultaneously identical operating system environment for all candidates. These more advanced pedagogical possibilities come from a system that is more difficult to implement because it works on students own computers instead of in a controlled institutional laboratory.

Third, social, cultural, and environmental factors affect the success of e-examinations. An interrupted electrical power supply, limited technical know-how, and negative personal perceptions are some of the challenges affecting the conduct of e-examinations in FUT Minna Nigeria. In Tasmania the BYOD challenge is to make the system operate on an increasing variety of user equipment, including tablets.

Fourth, if institutions are to transition to e-examinations, one means to facilitate this move is by using computers to imitate other assessment techniques. These techniques include multiple choice questions (sometimes read by machine scanners) and short answer questions or essays (usually

marked by human assessors). However, higher order thinking is usually demonstrated through open-ended or creative tasks, and in this respect the Australian system shows promise, by providing the same full operating system and software application suite to all candidates, thereby facilitating assessment of such creative higher order thinking. Students' responses can include data files created with sophisticated software tools, illustrating the capacity for assessing creativity in this e-examination system.

Finally, the two cases illustrate the potential tension between "online" or networked reticulation of questions and answers, as opposed to "offline" methods. The former can be implemented using "thin" clients or with BYOD equipment "locked down" by proprietary software. This provides a restricted assessment environment for candidates, but faster startup and collection of student responses. The offline methods require computer startup or booting processes which are unfamiliar, but thereafter do not depend on technology outside the control of the candidate; therefore the offline methods are more technically resilient.

The researchers' intention in presenting e-examinations in two different countries is to assist stakeholders (including lecturers, invigilators, candidates, computer instructors, and server operators) in identifying ways to improve the process. One proposal, which arose from the analysis of the existing e-examination systems in Nigeria and Australia, is to design a form of "live" operating system that is deployable over the Internet. It would use public key cryptography for lecturers to encrypt their questions online. These questions would then decrypted by the administrator or students when given the key at the start of the e-examination session. Such a system would cater for both subjective essay-style questions and objective questions. This could provide a solution for courses delivered as MOOCs to candidates using BYOD computers; however, at this stage authentication still requires a trusted individual to assure candidate identity and an assurance the assessment was done under examination conditions.

This study was conducted at the institutional level, so the design proposals for any future system are broad-brush only. Due to this limitation, further details about the user interface, question design, end-to-end e-examination management, or interface with the local student management computer system, are beyond the scope of this paper. Each of these aspects would be more properly dealt with at the local level of the individual institution or organisation.

CONCLUSION

The prospect for more extensive use of e-examinations is highly appropriate for a wide range of disciplines, and probably inevitable. This is not to say they will be applicable in all disciplines; some subjects will clearly be more suited to the technique than others. This may also be affected in the future by changes in the ways subjects are taught. For example, studio- and laboratory-based courses may well be taught entirely by live link-ups, and other traditionally face-to-face teaching methods could be replaced by virtual reality technologies.

The comparisons between the two universities suggest there will be a productive convergence of the approaches in future. Dedicated buildings and equipment put considerable strain on resources; these specialised uses may not be sustainable without public-private partnerships. However, the ease of deployment using a web-based strategy is one that overcomes the difficulties associated with preparing and distributing USB sticks. The administration of questions over the Internet should be a major concern and is one way in which a cryptographic e-examination solution could avoid hackers hijacking the questions online and thereby imperilling fair testing. The methods of cheating identified, for example, by Dawson (2016) can be addressed by more sophisticated strategies; e-examinations can identify and respond quickly and uniformly to such constantly developing attacks.

One future design proposition is a web-based strategy for a virtual machine, which is launched into candidates' computers at the start of each e-examination. This would retain the benefits of having an entire operating system for the assessment period and ensure every candidate has precisely the same

software tools. It would also move e-examinations beyond knowledge-recall to the assessment of higher-level thinking and creative professional design skills using sophisticated software tools. At the same time, security needs will be paramount, and therefore the system would possibly require and incorporate biometric (and less personal supervision) to ensure fairness (as will other global security formats).

The unique contribution of this research has come from uniting the user-experience and other factors affecting the conduct of e-examinations in Nigeria and Australia. The comparison of the e-examinations systems assisted the authors to devise a new system that contains the best features from both countries. The new system is a form of BYOD externally booted e-examination (as in Australia) that is deployable over the Internet with encryption and decryption features using public key cryptography (Nigeria). This will allow lecturers to encrypt their questions and post them online while the questions are decrypted by the administrator, or students are given the key. The system will support both objective and open-ended questions (possibly essays and creative design tasks). The authors believe this can re-define e-examinations as the "gold standard" of assessment.

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