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eExam symposium: design decisions and implementation experience

Andrew Fluck [0000-0003-1301-4615], University of Tasmania, Launceston, Australia, Andrew.Fluck@utas.edu.au
Hreinn Pálsson, University of Iceland, Reykjavik, Iceland, hpal@hi.is
Martin Coleman, Monash University, Melbourne, Australia, Martin.Coleman@monash.edu
Mathew Hillier[0000-0001-9990-0479], Monash University, Melbourne, Australia, Mathew.Hillier@monash.edu
Daniel Schneider[0000-0002-8216-4820], Federal Institute of Technology (ETH), Zurich, Switzerland, Daniel.Schneider@let.ethz.ch
Gabriele Frankl, Alpen-Adria University, Austria, Gabriele.Frankl@aau.at
Kristiina Uolia, CSC, Espoo, Finland, kristiina.uolia@csc.fi

Abstract. Increasingly, student learning is online or computer-mediated. Keyboards and screens are replacing pens and books. This is just as true in schools as in universities. These educational institutions are socially conservative, especially with respect to high-stakes assessments that credential the awards they make. Gradually, computer-based assessments are being trialled, in a multitude of forms. This symposium brought together a diverse group of such trials from Iceland to Australia. Geographically diverse, they represent a variety of approaches to eExams. Some use institutional equipment in dedicated spaces on campus. Others allow candidates to use their own computer, either under a security blanket or by booting from an alternative to the internal hard-drive. Each of these technological approaches has different sets of educational affordances. We are still evaluating the benefits and barriers for these different approaches. Some institutions value the time saved for teaching staff through automated marking. Others look at the entire assessment reticulation process, from examination composition to return of marks to candidates. Yet another group look at the potential for curriculum transformation arising from computer use at the assessment stage. Participants shared their design decisions and practical implementation experiences. Going forward, we may see commonality emerging that will make eExams convenient, reliable and educationally beneficial.

Keywords: eExam, computer, assessment.

1 E-exams at the University of Iceland

E-exams at the University of Iceland have been used since 1998. The system was written in Perl, and works well within our context. E-exams can only be taken on

computers that are wired into the campus network (i.e. in computer labs). The examinee is given a username and a password that are only valid for the exam in question. Access to the Internet can be controlled; students of law are, for example, permitted to access the Archive of Icelandic Law on-line.

Access is always given to Microsoft Office. Two directories are open to examinees: “Fetch”, where they open the examination itself along with permitted digital aids; and “Save”, where their solutions are stored. Students log-in for each e-exam, and then all their activities and time of saving documents are monitored on-line throughout the e-exam. Fig. 1 is a screenshot from LabStats Version 5.2.50102.168 by Computer Lab Solutions which is used in combination with our own monitoring system which details the names of documents and times when last saved by each candidate. Once the examination is over, all the solutions are saved to the home directories of their teachers.

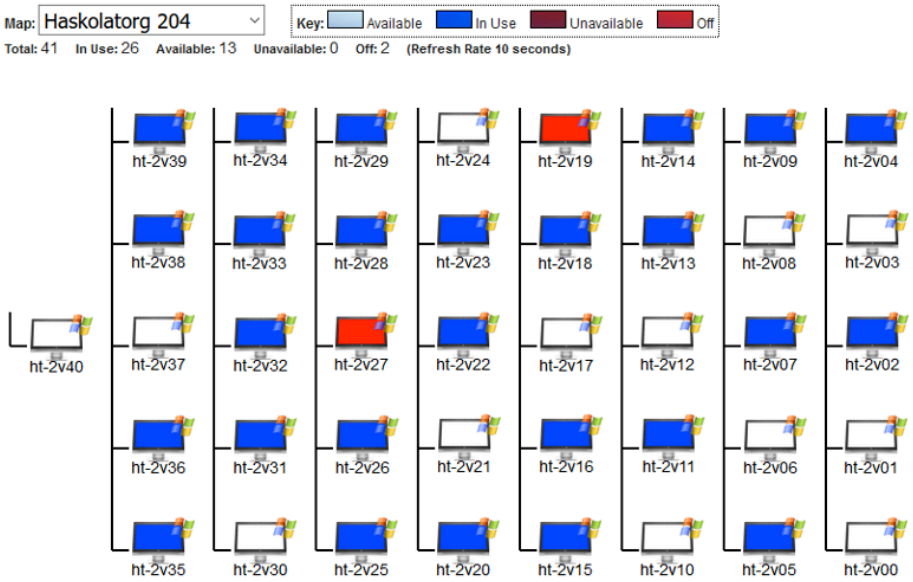

Fig. 1. Monitoring of e-Exams at the University of Iceland

In the academic year 2016-17, 10% of all examinations were submitted as eScripts, with all of the written exams in the Faculty of Law conducted as eExams. eExams are also used a great deal in Business (where students use spreadsheets), and in English, Icelandic for foreigners, Social Work, Computer Science and other subjects. Many students with special needs access eExams. In and out of examination seasons, we had eExams on 126 different dates, showing the demand for eExams.

The eExams have several noteworthy features. First of all, the scripts are readable! In practice, we have found the reporting of grades is much faster, and the process is ecologically sustainable because less paper is used. The Icelandic Lawbook (Lagasafn) has not been published on paper since 2007, so e-Students have direct

access to it and are much faster at searching and finding proper articles to cite than if they were working with a book. Other permitted aids can be placed in the Fetch-directory and searched electronically.

However, the system is not user-friendly, especially to administer, and a system is sought where students can bring their own device. Third-party programs require more sophisticated control measures to cover a broad spectrum of needs from simple word processing to mathematical functions. When browsers and operating systems are updated certain features may be affected.

It is quite clear from our experience it is absurd to test students with traditional paper and pencil when they need to solve problems using a spreadsheet like Excel. Computers are used every day in business, and have become the proper instruments for writing and problem solving. In addition, students are no longer used to paper and pencil on an everyday basis in their learning programs.

Future directions are expected to provide a user-friendly integration of eExam solutions with third party programs, as well as direct and secure integration with Student Information Systems (SIS) and the institutional Learning Management Systems (LMS). We also anticipate adaptive exams, where questions are selected based on the examinees knowledge and skill on a progressive basis through the test period. For economic and practical reasons, a BYOD – Bring Your Own Device solutions will be needed to offer eExams to all students.

2 Transforming exams across Australia: Processes and platform for e-exams in high stakes, supervised environments

Electronic examination and assessment systems pose a challenge in both finding or creating a solution that is effective and practical from a real world and software engineering perspective. Any proposed solution must be flexible to allow for a range of assessments, taking into account the requirements and expectations of multiple stakeholders such as students, teachers, administrators and technical support. This includes requirements for being easy to use, promoting quality educational outcomes, being open enough to prevent vendor lock-in, provide access to fine grained performance data, practical to implement, secure, and efficient to support. The technology and procedures for such systems should ideally slide into existing institutional practices while providing a pathway to transformative educational outcomes (Puentedura 2013).

We are faced with a growing disconnect between the way high stakes testing is conducted using pen on paper, and students' everyday experiences of study, work and life. Computerised exams offer the opportunity to frame questions that require very complex, constructed responses, which could not be posed without a computer (Fluck & Hillier 2016). This pedagogical affordance can lead to authentic assessments, providing candidates are not limited to the confines of a single software application. Instead, students must have a range of 'e-tools of the trade' at their disposal to best demonstrate their capabilities. However, there is a great challenge in transforming

current examinations to computer. The examination period in a modern university is a major operation, involving thousands of students. They are provided with precise materials at specific times over a period of two to three weeks. This presents both logistical and scalability requirements to be met. However, such requirements may come into direct conflict with the need to enable authentic assessment types that best meet the needs of twenty first century educational outcomes. Often solutions in the market appear to satisfy scalability and administrative concerns at the cost of narrow pedagogical affordances, being limited to a text box and a narrow range of selected response quiz like questions.

In our nationally funded Australian project, we have been working towards satisfying many of these requirements with a guiding principle of enabling authentic assessment at scale. The current incarnation of an e-Exam platform under development and undergoing trials across ten universities uses purely open source components and is designed to work with common high stakes exam practices.

The system uses a live USB to boot the candidate's own computer (BYOD). It provides a modified version of Ubuntu, with a common set of applications such as Office suite, multimedia players, and software development kit to all candidates regardless of their hardware brand. An encapsulated version of the Moodle learning management system can also run without a network connection, which lessens the risk of a single-point-of-failure during an exam event.

These features provide security and resilience. At the end of the exam, the USB sticks are collected and responses retrieved in bulk via large hubs and then sent to the assessor electronically. The USBs can then be recycled for the next exam. The system is under continuous development, with the roadmap shown in Fig. 2.

Start >	> *Current*	> > >	> > >	> > >	> **Future**
Get Ready	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Phase 5**
Institutional approvals, research ethics, hardware and infrastructure	Paper equivalent small scale. Basic doc exams to begin!	Post-paper small to medium. Expanding the media landscape.	Medium to large scale. Adding the power of an onboard LMS.	Whitelisted and logged Internet Network BYOD exam.	Open but fully logged Internet Network mixed mode BYOD exam.
	Crawling	**Walking**	**Running**	**Jumping**	**Flying!**

Fig. 2. Roadmap for *Transforming Exams* project in Australia

Trials of the e-Exam system have been conducted in a variety of disciplines including language translation, knowledge management, ethics and social issues, education, business, and computer programming. Students who have used the e-Exam system have reported high levels of satisfaction and benefits to their writing under exam conditions (Hillier 2015). Similarly, teaching staff have anecdotally reported

that their marking time has been reduced. More information on the Transforming Exams project and the open source system is available from http://transformingexams.com.

3 Design choices for SafeExamBrowser

SafeExamBrowser (SEB) is a kiosk or lockdown browser, which secures computers used as exam clients, while an exam running on a web server is taken. SEB is open source and available as freeware currently for Windows, MacOS and iOS devices. SafeExamBrowser generally works with any web based e-assessment system such as Moodle, ILIAS, OpenOLAT, Inspera Assessment, Haiku Learning, Open edX, SBAC, Canvas, Brightspace etc.. A growing number of learning management and exam systems provide additional integration with SEB for increased security. Besides running online exams in its built-in web browser, SEB can start third party applications, which have been permitted during the exam. Initially targeting exams taken on managed lab computers, current versions of SEB can also be used for increasingly popular BYOD exams. The design choices made while building SEB, focused on its modularity, openness and independence from a centralized server or cloud service. Other key concerns were ease of use and compatibility with a wide range of equipment contexts. This has led to SafeExamBrowser being used worldwide for various kinds of e-assessments, including the proposed national online assessments of literacy and numeracy in Australian schools.

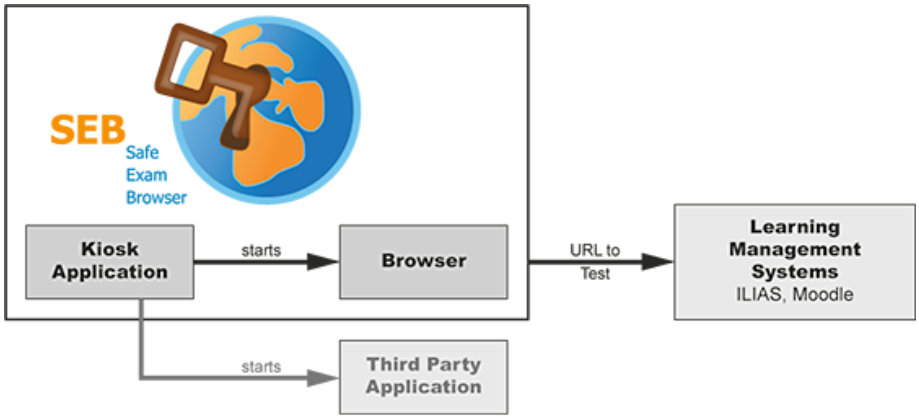

Fig. 3. How the Secure Exam Browser works

Fig. 3 shows how the system works, in a nutshell, illustrating the critical elements of SEB's technological implementation. Optionally an SEB exam setup can include the provision of a virtual desktop to better support third party applications and the rich use of these software tools during exams. The source code is subject to the Mozilla

Public License Version 1.1, and can be downloaded from http://safeexambrowser.org, and adapted by different organisations. As SafeExamBrowser is open source, anyone can review the code to verify that SEB does not connect to any centralized servers, and is not collecting user data.

SEB is used extensively around the world, with ½ million exams conducted using it in 2016 in mathematics, computer-science, engineering, economics, life sciences, natural sciences, physics and other disciplines. Starting in 2008, its development at ETH Zurich has been publicly co-funded (2010-2014) by national Swiss e-learning programs, and is now sustained by the SEB Consortium, which is funded by membership fees and donations from educational and academic institutions (public and private), foundations, public authorities, and companies (for profit and non-profit). Future developments will improve support for controlled and secured use of third party applications and additional resources like specific websites, web databases and web applications in exams. This will require pedagogical innovation by educators, and provide new experiences for learners.

4 The Secure-Exam-Environment: eTesting at the Alpen-Adria-Universität Klagenfurt

The manifold advantages of online-testing face a plethora of technical as well as organizational challenges. Usually, computer rooms at educational institutions are far too small for large online-exams. Looking for a sustainable possibility for mass online-testing, the Secure Exam Environment (SEE) system was developed in 2011 to make use of students' own devices. SEE restricts access to the internet, the student's own files and all external devices. This is done by booting a Linux-image via network (PXE), installing a virtual computer, and mounting a version of Windows (Fig. 4). The Safe Exam Browser is then used to connect to the institutional learning management server (Moodle) to provide the exam questions. Further security is provided by imposing a time window and IP address range restrictions.

This design of SEE provides good security, and enables candidates to use supplementary software for testing like spreadsheets, programming or mathematical tools (e.g. Excel, Eclipse, GeoGebra). As an additional service, we can offer exams online, allowing students to freely choose the time and day of their exam during a predefined week ('slotted' exams).

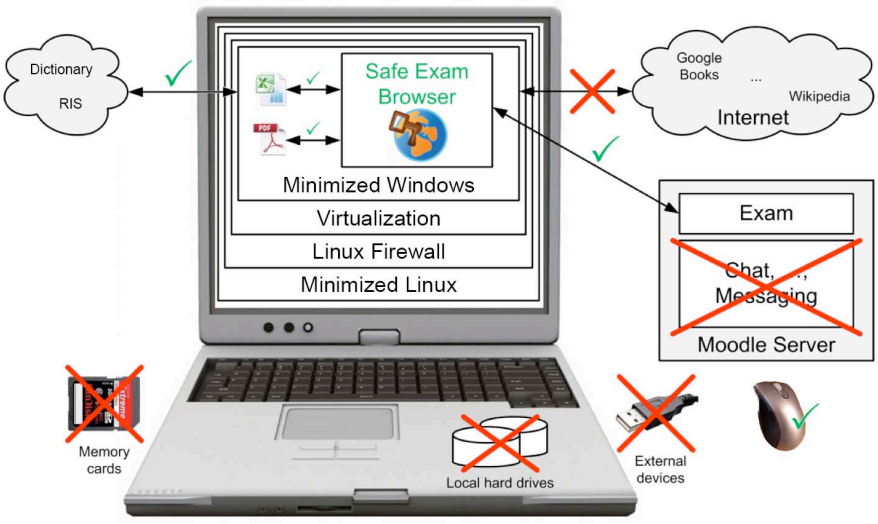

Fig. 4. Secure Exam Environment design features

The general availability of eExams has improved the readability, structure and format of free-text answers. It provides automatic grading of semi-structured question types, and constructive alignment with the teaching environment. Therefore users of SEE understand that "a good pedagogical respectively didactical design ensures that there are absolutely no inconsistences between the curricula, the teaching methods, the learning environment and the test method" (Biggs & Tang, 2011). SEE online exams facilitate the testing of knowledge in the way it was taught. Lecturers have reported correction efforts are severely reduced and text is more structured in SEE. They can benefit from joint synchronous corrections with colleagues, and mark exams using mobile devices. In addition, online exams (normally) do not get lost! Up to 40% of exams at our institution use SEE. Students usually get their exam results faster, with individual feedback of automated answers. They get no hand-aches when writing long exams, and enjoy transparency over answers. They regard the process as fairer, because their script is anonymous, and randomized questions and answer complicate cheating. 83% of surveyed students were very positive, or positive, about SEE.

Nonetheless, there are current challenges because Ethernet LAN sockets are increasingly missing from the latest laptop computers. This can be overcome by using adapters, and we are conceptualizing alternative solutions for more secure online testing with network monitoring. Extending the range of venues will expand SEE use, and future exams can be individualised using this platform.

5 Exam in Finnish Universities

The Exam system was built by Finnish Higher Education institutions in 2007, and uses the FunetEduPerson authentication system for each user for logging in. This provides links to institutional databases which identify the user-role (student/staff), e-mail address etc. Exam is accessed with any web-browser – preferably Firefox or Chrome. The exams are taken in dedicated Exam studios, where network access has been limited to the Exam server alone. Students can book a day and time for their chosen Exam studio appointment. Questions can be opened one by one and can be answered in a rich text box answer space that can be expanded or made full-screen. Other question styles include auto-marked multiple-choice questions. Mathtools can be used for equations. Throughout the exam, student responses are backed up onto the server every minute. Exam is excellent at supporting language testing in Finnish, Swedish and English; Russian will be added soon. Copy-paste functionality has reportedly improved the quality of student essays when using Exam.

The client/server architecture for Exam is illustrated in Fig. 5. All users (administrators, teachers, students) access the system via a web browser. Exam can operate as a 'software as a service' or as a local implementation. The system uses the representational state transfer software architectural style and javascript object notation to include rich media with low network bandwidth. It links to the European Schengen Information System and the internationally federated EduPerson schema for identity authentication. There is restricted access to taking an exam: IP number and time restrictions plus user identification are in place.

Twenty-four universities across Finland are using the Exam system. About 10% of all exams in Tampere University of Technology use Exam (10 000 in 2016). Different types of software can be used to add attachments to the exams. These can be decided by the universities: which tools will be supported in Exam studios. Each university can have their own Exam server (e.g. exam.app.jyu.fi), or use one of the 8-9 instances in the CSC datacentre. Not only does the system link with student management systems to identify enrolments, it also integrates with academic administration systems to return assessment evaluations. Exam is being developed to support data exchange among universities: a student can take an exam in another university's Exam studio, or exams can be graded by teachers in other universities. The system has reduced teacher workload and manual work, and decreased costs. It is multicultural and multilingual, and provides advanced candidate analytics. Students have been very positive, and are critical of slow take up by teachers. They like getting their results by e-mail!

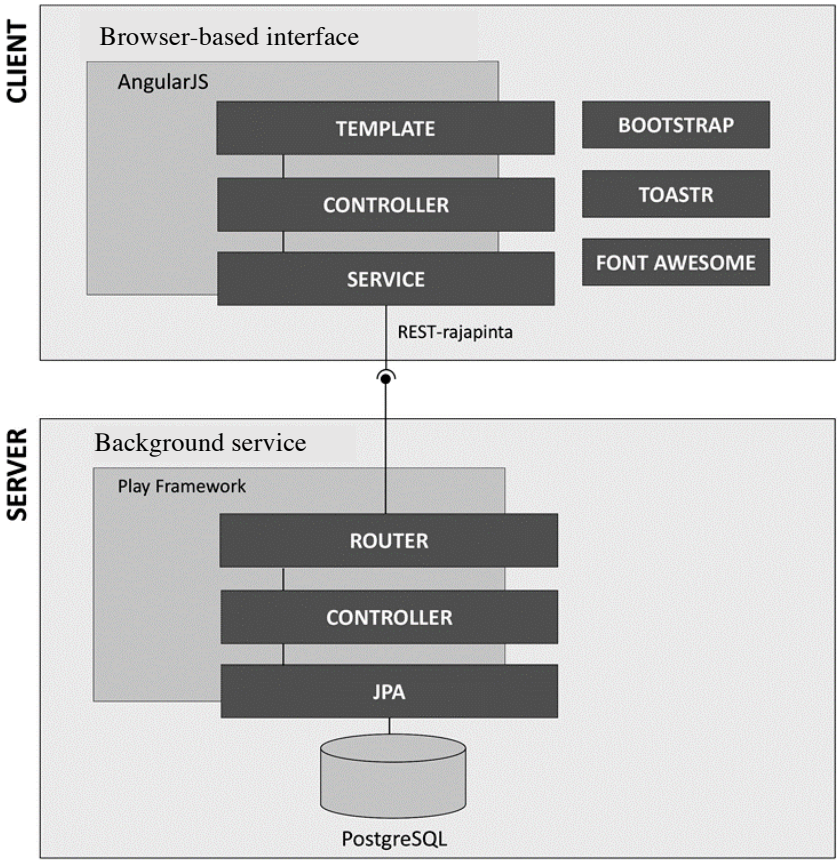

Fig. 5. Exam system architecture

Exam is being considered for university entrance examinations (these are attempted AFTER matriculation results are published, and are organised by individual universities). Currently Exam is private to the university consortium: it will be made open source using the European Union Public Licence in late 2017.

6 Conclusion

The eExam symposium provided an excellent opportunity to share the design objectives and penetration outcomes for a range of technical approaches. Increasing proportions of eExams are being done, with student positive acceptance, better alignment with teaching, and perhaps because contract cheating is raising the importance of credential integrity. It is not clear at this stage whether transitioning assessment into these richer information technology environments will transform

teaching content or curricula. It is clear that more research into the extent of this linkage between assessment context and curriculum content is required.

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