Scoping E-Assessment Tools for Engineering

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Introduction

Context and Background

Within the engineering faculty at Monash University, there has been a movement over the last few years to implement a more digital approach towards the assessments within each unit as digital learning systems offer greater flexibility and allow "learners and teachers to extend beyond the traditional schoolrooms" (Sarrab, 2013). This can be seen through increased development and use of Learning Management Systems (LMS) which has been driven by blended-learning and active-learning approaches. Despite this, the majority of final examinations are delivered using paper-based approaches, which often consist of question and answer booklets.

This traditional system can be an effective method of assessing student knowledge of coursework, however, its effectiveness does not scale with increasing student enrolments in higher education. The number of students enrolled at Monash University has increased from 57,067 students in 2015 to 66,626 in 2017 (Monash University Annual Report 2017, 2018). As of 2019, there are 7,577 enrolled in the engineering discipline (Monash University, 2019). The paper-based exams require large volumes of paper to be printed, great amounts of time and tutor efforts to scan, send and mark the papers, as well as sufficient capacity to store the papers in a secure location (Appiah and van Tonder, 2018). Along with the increasing resources required to implement a paper-based exam, some engineering units cannot offer an authentic reflection of the in-semester content that is strongly dependent on engineering-specific software. This limits the ability of a paper-based exam to effectively assess students' knowledge and learning outcomes.

Mora *et al*. (2012) proposes digital technology to be a potential solution that can overcome issues arising from large enrolment numbers and overcrowded classes, which can be extended to assessments. However, the process to transition paper-based assessments to digital platforms has been difficult to establish given the variety of assessment types offered within engineering. Example assessment types include: hand calculations and derivations; hand and computer-aided drawings; programming; essays and reports. The engineering faculty does not currently adopt a digital system that addresses all of these assessment types.

Aims and Purpose

This study aims to identify and categorise the types of assessments currently used within engineering and explore the e-assessment tools that can effectively address the challenges associated with final examinations in engineering at Monash University. Best practices regarding the implementation of these tools will be investigated to ensure a positive experience for students undertaking the assessment and staff assessing the student output.

Methodology

Initial Research and Exploration

The first aspect of this investigative project identifies a list of several key engineering units that provide sufficient variance in the unit learning outcomes and the assessment types. The units are shown in Table 1 and currently do not implement e-assessment tools for the exam.

Unit Code	Unit Title	Unit Focus	Assessments
ENG1060	Computing for Engineers	Computing	Computing
MEC2402	Engineering Design 1	Design	Drafting, part and assembly drawings
MEC3451	Fluid Mechanics 2	Technical	Derivations, hand calculations
MEC3456	Computational Analysis	Computing and Numerical Methods	Computing, hand calculations
MEC4404	Professional Practice	Engineering Profession	Theory, hand calculations

Table 1 - Details of engineering units considered in this study.

The past exam papers for these units were reviewed to determine the typical question types offered in exams and how it linked to the unit learning outcomes. It was clear from this exercise that no single e-assessment platform or tool that currently exists, which could address all the question types in an exam scenario. Therefore, each unit was individually assessed and matched with various e-assessment tools that were studied and evaluated. The e-assessment tools were evaluated upon three key criteria:

1. The ability to meet the exam learning outcomes
2. The authenticity of assessment
3. The feasibility of implementation within an exam scenario

Unit Specific Investigations

The ENG1060 exam consists of questions involving a programming language, namely MATLAB. Students are expected to write code and use numerical methods to solve simple engineering problems. Students achieve this using calculators in a paper-based exam. The aspects of computing and hand calculations for this unit can greatly benefit from e-assessment tools and provide a more authentic experience for the students, especially since students are assessed on their ability to code in MATLAB during weekly laboratories. The e-assessment tools investigated were: Moodle, the Monash Virtual Environment platform (MoVE), and Monash's in-house e-assessment platform.

The MEC2402 exam featured majority of the marks dedicated towards drafting engineering drawings, both a detailed part drawing and an assembly drawing. A significant portion of the marks were not allocated towards hand drawing skills, but rather their ability to construct engineering drawings to Australian Standards was addressed. Students utilise SolidWorks to generate 3D parts and drawings throughout the in-semester assessments. Hence, a more authentic experience for students could be provided if the same software was offered during the final exam. The e-assessment tools investigated for MEC2402 were the SolidWorks Certification Program and its exams, the Moodle platform, and LanSchool.

MEC3451 and MEC3456 both have heavy emphasis on calculations and derivations within their exams. Whilst MEC3456 has significant MATLAB content throughout the semester, computing ability was not one of the learning outcomes assessed in the exam. Rather, emphasis was placed on the mathematical aspects of the unit. Likewise, the MEC3451 exam requires students to derive equations involving numbers and variables. Therefore, these units require e-assessment tools that can capture and assess handwriting or enable a process whereby equations are easily and quickly transposed in digital form. MathType from Wiris and Latex type-setting options were investigated.

MEC4404 had perhaps the simplest exam in terms of types of questions being asked. Most of the questions were extended worded response questions based on theoretical content. There were some basic calculation type questions as well, but all questions from a past exam could be covered using features within an LMS. Hence, Moodle was the only e-assessment tool investigated for this unit.

Outcomes

ENG1060 – Computing for Engineers

Moodle promised to be an effective e-assessment tool for use in exams due to its ability to construct quizzes. These quizzes featured many questions types including, numerical input, short answer, essay style, multiple choice, drag and drop, and calculated answers. Another benefit of Moodle is that it is open source, which allows creators to develop their own question types. A Moodle quiz was constructed based on a past paper-based exam for this unit using a mix of multiple choice, numerical, short answer and essay style questions. The essay style questions also supported organised file uploads, which would be beneficial for students to write script files within MATLAB and then upload them to the relevant questions. Whilst Moodle shows great capability as an e-assessment platform and would satisfy the first two evaluation criteria (see Methodology), it may not be suitable for the final criterion because the unit content could still be accessible to the students, which provides opportunities for cheating. Whilst the unit content can be hidden post-semester, it would take a combined effort to ensure all content is hidden on Moodle for all units. This leaves significant room for error. Hence, a dedicated separate platform similar to Moodle would be beneficial. It would allow for exams to be entirely separate from the rest of the unit and could potentially satisfy the third evaluation criteria if specifically tailored for exams.

The Monash Virtual Environment (MoVE) is a platform that allows students to access key specialised software from any device via a browser without needing to install the software locally. This platform satisfies both the first and second evaluation criteria as utilising MATLAB in an exam assesses the unit learning outcomes as well as providing a more authentic assessment experience. There were concerns about latency and running speed of using MATLAB through the MoVE platform, so some benchmark tests were performed. The benchmarks were using MATLAB's in-built "bench" function, which measures the execution speed of six different tasks compared against other devices. The results showed that the average time difference between the MoVE platform and the fastest device for each task was 0.36 seconds, with the greatest difference of 1.40 seconds for a 3D task and the lowest time difference of 0.0208 seconds for a numerical task. These time differences support the imperceivable time-lag differences between MATLAB on MoVE and that locally installed in a laptop. One key aspect that was not tested within this project was load testing, which is relevant to the third evaluation criteria. The MoVE platform would need to serve potentially thousands of students during an exam, which would cause an immense server load. Load testing would need to be undertaken to ensure that there is appropriate capacity.

Monash University has developed an in-house e-assessment platform, which has been used for in-semester assessments and exams by multiple faculties including Law, Arts, Medicine, Nursing and Health Sciences. The e-assessment platform is based on Moodle's quiz capabilities but has been modified to improve the student and staff experience with a dedicated focus on exam scenario assessments. This solves the issue that Moodle has with satisfying the third evaluation criteria. For this project, this platform was tested by creating a mock e-exam that consisted of two main sections. The first section was based on questions from a previous paper-based exam for ENG1060. These questions were modified to require utilisation of MATLAB for coding and analysing code rather than using calculators, hand calculations and hand writing code. In addition, template scripts were provided to students via the platform for them to use and/or correct. The second section was based on in-semester computer-lab questions which incorporate MATLAB practices but were modified to suit the exam time constraints. One shortfall of the e-assessment platform is that it does not currently allow for file uploads like Moodle does. This meant that essay textboxes were left for students to copy and paste their code scripts into the relevant question boxes. Once the e-exam construction was completed, six former ENG1060 students participated in completing a selected mix of the exam questions and provide feedback via a short survey afterwards. Similarly, two demonstrators were tasked with marking the exams and then again, their feedback was collected on a short survey.

Students deemed the following aspects to be important when considering e-assessments: to have similar opportunity and ability to express knowledge learnt, including MATLAB knowledge, when compared to a paper-based exam; questions posed are correct, clear, easy to navigate and annotate. The students were most concerned with diagrams loading, links working correctly, responses being saved regularly and automatically, and hardware issues/failures. There were three key Likert scale questions that were asked of the students:

1. How would you rate the overall experience of the research e-exam that you sat on a scale of 1-5? (1 being very poor and 5 being very good)
2. How would you rate the difficulty of the questions derived from past paper exams on a scale of 1-5? (1 being much more difficult and 5 being much easier)
3. How would you rate the difficulty of questions derived from in-semester computer lab questions now that there was strict time limits on a scale of 1-5? (1 being much more difficult and 5 being much easier)

The average rating of the students for Q1 was 4.17/5. Students expressed that it was a more authentic assessment and more in line with in-semester content. All but one student preferred to sit the e-exam rather than a paper-based version and found it easy to use the e-assessment platform alongside MATLAB. The students found that the questions derived from past paper exams were easier (average rating of 4.33/5 for Q2) to complete given the addition of being able to use MATLAB. The average student rating for Q3 was 2.33/5, showing that the questions from section 2 were more difficult in terms of time limitations. Thus, question design is of utmost importance when transitioning questions from a paper-based exam to an e-assessment platform. Clarity of the marking and being able to award consequential marks, even for questions which by nature are “right or wrong” on a digital platform (e.g. numerical answer questions), were the main concerns that the two markers expressed. Overall, both markers had a favourable experience with using the e-assessment platform for marking, and both found it easier to mark the responses online when compared to marking a paper-based exam for this unit. They expressed that “legibility” of typed code was beneficial and the ability to “copy paste code into MATLAB” made it easier. Some of the issues with the online marking were that questions with marks allocated in multiple parts were difficult to provide consequential marks and feedback for extended response questions. Marking of students’ code was also more difficult as the feedback textbox was separate from the response and it was difficult to target the exact location of the error. One marker found it took less time to mark the exam online than marking a paper-based exam, and the other marker found it was about the same due to some of the issues mentioned above.

MEC2402 – Engineering Design 1

For MEC2402, the first e-assessment tool that was analysed was the SolidWorks Certification Program. This program offers numerous certificates for various SolidWorks skills including Mechanical Design, Simulation, Drawing, etc. and issues them based on the score from a set exam/test. Whilst these exams and tests are excellent methods of testing students’ ability of SolidWorks and provide an instant pass or fail immediately after completion, the certificates do not meet the first evaluation criteria and do not line up with the unit learning outcomes, therefore this e-assessment tool was dismissed.

Using a platform like Moodle could easily work for this unit as well. A mock test using the Moodle Quiz function was developed which provided the questions for the students and were designed for them to use SolidWorks to create engineering drawings and then upload them to Moodle, which was the key learning outcome of the exam for this unit. As there were no numerical or short answer questions (based on past paper exams for this unit), the other functionalities of the Moodle Quiz were not utilised. Therefore, any e-assessment tool or platform that can deliver the questions to the students and accept file uploads as submission of answers would be suitable for this style of unit. As the Monash e-assessment platform does not currently support file submission, it was not investigated for use for this unit.

Since Moodle (and the e-assessment platform) has a lock-out function for the quizzes, it cannot be used if the students require access to third party programs. Students cannot be given unrestricted access to the laptop/device as that would provide significant opportunities for cheating during the exam. Hence, LanSchool was investigated as it is a third-party monitoring and lock-down software that is readily available within this institution. It can block or allow programs, software, domains, URL's, and even hardware such as USB ports and CD drives through whitelists and blacklists. This program can be used to lock the assessment environment such that only Moodle and SolidWorks can be accessed. LanSchool would be appropriate for ENG1060 with the e-assessment platform and MATLAB. This e-assessment tool was not evaluated based on the criteria set out in the Methodology, as this tool would simply be used to aid other e-assessment tools to satisfy the third evaluation criteria (implementation in exams).

MEC3451 – Fluid Dynamics 2 and MEC3456 – Computational Analysis

Upon review of the past paper-based exams for these units, and consulting with the unit coordinator for MEC3456, it was determined that the exams for both units were almost entirely focused on hand calculations and derivations. These are the most difficult question types to transition to a digital format as constructing equations using a keyboard is very difficult, time consuming and unfamiliar. Even though Latex-type settings can effectively create lines of equations, it was quickly dismissed as being used within an e-assessment format as it is too slow and may be too difficult for students to learn, not satisfying evaluation criteria 2 and 3. From this, it was concluded that tablets and styluses would be needed to capture student handwriting for the most authentic exam experience (criteria 2). Tablets and styluses would be difficult, if in the future, there were plans to move towards a bring-your-own-device approach for the e-exams, as variation of tablets and styluses would have a significant impact on the students' performance within an exam.

One key software that was investigated for use with a tablet and stylus scenario was MathType from Wiris. MathType 7.0 has handwriting recognition that converts writing into text. The handwriting recognition was exceptional at determining the characters and all the different types of mathematical symbols. It successfully recognised all the different symbols that were required for a MEC3451 and a MEC3456 past exam paper with minimal errors, averaging 1 character to be rewritten per line of equations for both exams. The web version of the software has added functionality in integrating with online systems such as the LMS or Google Docs. The online version was severely limited by the size of the handwriting input box. This was a non-resizable box that could only fit approximately 20 characters (in small writing). This issue was solved on the desktop version which automatically expanded the input box as the stylus approached the edges. There were two significant issues discovered with this software upon testing. The first issue is ease of use for new users. The software takes time for the user to get acquainted with all the nuances and become proficient at using it. This issue could be easily solved by introducing the software to students multiple times throughout the semester. The second issue is, even once acquainted with the software (which yielded significant time savings), the time taken to write a line of equations is still far too long, at times taking up to 6 times longer to write the same equation on a tablet in MathType than writing it by hand. This would be unacceptable within the strict time limitations of an exam. So, whilst MathType can meet the requirements of the first two evaluation criteria, it does not satisfy criteria 3.

MEC4404 – Professional Practise

For this unit, the text-based questions were simply created as essay-style questions using a Moodle Quiz, and the simple calculation questions were added as numerical questions. These assessment types are great candidates for e-exams and can be accommodated using a single platform such as Moodle or the Monash e-assessment platform. This unit was not tested on the e-assessment platform due to timing constraints. However, both essay-style and numerical style questions have proved successful in other faculties.

Summary of Outcomes and Considerations

Types of Assessments	E-assessment Tools that can be used
Computing assessments (e.g. ENG1060)	• Moodle Quiz or Monash e-assessment platform in combination with computing software (e.g. MATLAB) • Monash Virtual Environment platform for remote hosting of key programming software • LanSchool for exam environment lock down features
Drafting and engineering part and assembly drawings (e.g. MEC2402)	• SolidWorks, to produce engineering drawings without the hand drawing component • Moodle Quiz or Monash e-assessment platform for delivery of questions • Moodle quiz or FTP method for collection/upload of drawing files • LanSchool for exam environment lock down features
Worded response and theory-based questions (e.g. MEC4404)	• Moodle quiz or Monash e-assessment platform for delivery of questions, collection of responses and exam environment lock down features
Light calculations and numerical answer-based questions (e.g. MEC4404)	• Moodle quiz or Monash e-assessment platform for delivery of questions, collection of responses and exam environment lock down features
Heavy derivations and complex calculations within a unit's assessments (e.g. MEC3451, MEC3456)	No appropriate e-assessment tools can fully allow an e-exam for these types of units; however, the following tools may be useful in combination with future technologies: • Moodle quiz or Monash e-assessment platform for delivery of questions • MathType software in combination with a tablet and stylus for collection of hand-written calculations (still not a proven method for e-assessment)

Table 2 - Types of Assessments Matched with Feasible e-Assessment Tools

Some of the key aspects to consider when implementing e-assessment tools are:

- The questions and/or the platform are easy to navigate and have proper scaling (if designed on a large monitor, does it scale properly down on a laptop)
- The questions are conveniently structured, having proper sections for each component of the exam (section for multiple choice, section for short answer, extended response, etc.)
- The questions need to allow the ability for students to express responses the same as a written response or better (hand calculations, for example, are not currently the same or better on a computer or a digital device)
- A visible timer always present on the platform or screen to ensure students do not need to go searching to find the time
- The saving of responses is automatic, saving on a timer and upon changing pages/questions (a visible notification of the responses being saved is also recommended)
- The screen real estate needs to be considered upon designing the questions and requirements of the exam; the size of screens should be able to display all required information at once, like spreading out papers on a table, and switching between e-assessment tools and software is non-problematic
- Reliable technology should be tested before the exam with backup options should it fail, such as automatic saving and replacement devices available

- Any formulae and/or equations that are required for the students to use can be directly copied rather than providing them in an image or diagram

Conclusion

This project demonstrates that many of the assessment types from the engineering units investigated would benefit from transitioning to using e-assessments, not only for the advantages of digital collection and storage of responses, but also being able to provide a more authentic assessment experience for the students and the potential for a reduced marking workload. As most engineering exams do not consist of only worded response questions types or only theory-based questions, it is difficult to find a single e-assessment tool that can completely cover all the different question types needed for the exam. However, a combination of multiple e-assessment tools can effectively be used to create and deploy an e-exam if they are implemented appropriately. Units that require complex hand calculations and derivation assessment types are still a significant issue for e-assessment tools to solve. A combination of hardware and software, such as tablets and styluses, in combination with handwriting recognition software, such as MathType, can help to assist with providing an authentic hand-written e-assessment. However, future e-assessment tools, or further development of existing tools, will be needed to complete the transition for these types of assessments. Whilst the tools studied in this investigation are not all the e-assessment tools that can be used whilst creating e-assessments, they can significantly help a unit to transition from paper-based assessments to e-assessments reliably and smoothly.

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