



Continuing the Journey: Engineering Mathematics and Students Making the Connection in Covid 19

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ABSTRACT

CONTEXT

Provides a brief overview of the engineering mathematics units at Central Queensland University and a detailed explanation of how the video teleconferencing (Zoom) is currently utilised to enhance the delivery of the suite of mathematics units during Covid 19.

PURPOSE

Investigates how academics utilise the available technology in the delivery of engineering mathematics units during Covid 19. In particular, it looks at the barriers and motivators for using the available technology.

APPROACH

Building on the research and experiences of staff involved in the use of the Tablet PC to provide feedback on formative assessment in engineering mathematics units, strategies are to be developed to implement and improve these practices in undergraduate engineering courses. Using a grounded theory methodology, the research team have a two-stage process. Stage one which is reported on in this paper uses the observations of the team to identify the barriers and motivators.

ACTUAL OUTCOMES

Central Queensland University has moved forward using the LMS (Moodle) for delivery of units that enable students to submit non-supervised assessment electronically, replacing paper-based submissions. Annotative devices enable academic staff to engage online students more effectively in online lectures and tutorials and with providing handwritten feedback on electronically submitted and returned mathematics assessment. The combination of the LMS (Moodle) and annotative devices have created almost paperless courses. As this success is recognised across the University, others are incorporating it into their programs. Students are the main beneficiaries of the efficiency of staff working with annotative devices. Add Zoom into the mix and students have an almost face-to-face like experience from anywhere.

CONCLUSIONS

Many of the initiatives introduced or perfected during COVID 19 to will continue as business as usual. One exception to this will be the take-home examinations as they proved problematic with regards to contract cheating. It is recommended that all engineering mathematics units include at least one supervised assessment. The invigilated examination would need to be conducted by the University's official Examination Centre.

KEYWORDS

Assessment, Covid-19, Academic Integrity

Introduction

Central Queensland University (CQU) has campuses and study centres across Australia but has had a long history of distance education. Prior to COVID 19 restrictions, approximately 65% of its students studied online. We believe a university's "purpose is not to transfer knowledge but to create environments and experiences that bring students to discover and construct knowledge for themselves, to make students members of communities of learners that make discoveries and solve problems" (Barr & Tagg, 1995).

The use of technology is becoming a significant element in the COVID 19 teaching/learning context. Ensuring that "students are able to interface with technology in a meaningful and purposeful way" (Dekkers, Adams, & Elliott, 2011) puts additional stresses on lecturers in this already stressful environment. Adams and Hayes (2009) found, that while the use of technology can have many positive effects, including improved attitude and increased engagement with mathematics, student experiences related to the effective integration of technology into mathematics classes were affected by the skill of the instructor using the technology.

The CQU Bachelor of Engineering (Co-op)/Diploma of Professional Practice (Engineering) is a 4.5-year full time undergraduate degree and is offered in both off and on campus modes. The four-and-one-half years includes a minimum of 48 weeks of work placement in the student's relevant discipline. CQUniversity engineering work integrated learning program incorporates Project Based Learning, Co-operative Education with Professional Practice, providing learning in context, both in formal and informal learning environments (e.g. in workshops and classes and project studios) and in employment in industry, integrated in the study program. Teamwork and problem-solving skills are learned alongside the technical content in an exciting real-world engineering environment CQUniversity Bachelor of Engineering is offered on campus (recommencing 2021) from the Rockhampton, Mackay, Gladstone, Bundaberg and Cairns campuses (CQU Handbook 2021). In 2021 there was approximately 600 students enrolled in the Bachelor of Engineering at CQU.

First Year Engineering Mathematics Units

In recent years, the mathematics aptitude of incoming students for the Bachelor of Engineering courses at CQU has generally declined, which has resulted in low pass rates in many foundation mathematics and technical engineering units. However, engineers' graduate expectations are not reducing; rather, more is expected from our next generation of engineers.

To address this widening skill deficit, a new mathematics unit was developed to help students recap their knowledge of mathematics fundamentals (MATH11247) before undertaking Applied Mathematics.

First year Engineering Mathematics units offered to students include:

- MATH11247, Foundation Mathematics unit is designed to provide students with foundation concepts, rules and methods of elementary mathematics. Topics covered in the unit include fundamentals of algebra, equation solving, exponents, logarithms, linear systems, inequalities, introductory trigonometry, area and volume, and trigonometric functions and ratios.
- MATH11218, Applied Mathematics covers fundamental topics in algebra, functions, complex numbers, matrices, vectors, and trigonometry
- MATH11219, Applied Calculus, builds upon students' studies in mathematics and cover key mathematics principles required for the CQU engineering degrees. Topics in included differentiation, integration, and sequences and series.

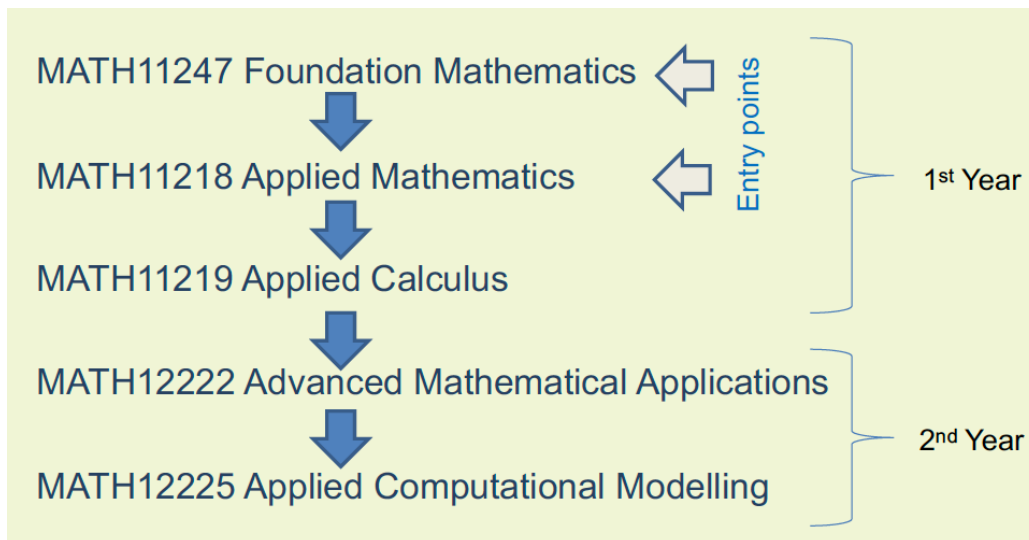


Figure 1: Student path for Engineering Mathematics Units

The progression (figure 1) for students in the Bachelor of Engineering is:

1. Students are enrolled in Foundation Mathematics initially.
2. Students can take the mathematics skills diagnostic test.
3. If the student achieves at least 70% on the diagnostic test, the student can opt-out of Foundation Mathematics and enrol into Applied Mathematics. Otherwise the student should remain in Foundation Mathematics.

Teaching Engineering Mathematics Online During Covid-19.

One significant issue faced by the academic staff is catering for the diverse mathematical backgrounds of students, this is particularly difficult when delivering units online. Although students are provided with extensive resources in the form of study guides and detailed textbooks, it is extremely difficult for some students to learn from text-based materials, especially when their mathematical background is limited. Additionally, many students struggle with learning mathematics externally and miss having the familiar teacher explanations as in their previous education. "The nature of mathematical sciences dictates that students need to hear the instructor explain the concepts and ideas" (Amin & Li, 2010, p. 47).

In 2020 all on-campus classes were converted to online delivery. Adoption of video conferencing technologies by universities enabled live lectures to be delivered to all students. When these are used in conjunction with the Tablet PC and annotating software the student experience more closely compares to that of a face-to-face classroom.

Zoom, for video conferencing, a Tablet PC and PDF Annotator[®] were used in combination to deliver mathematics instruction online. Zoom includes functions such as: screen sharing, chat, breakout rooms and recording. Lecture slides are mostly created using Word[®]. These are then converted to PDFs so that they can be annotated using PDF Annotator[®]. The slides are quite basic with minimal text or graphics and various questions. Plenty of room is left on each slide to facilitate working (Adams & Hayes, 2019).

Setting the Zoom room to 'join before host', allows the students to arrive before the lecture time and chat to each other. With the centralisation of Zoom timetabling and auto-recording and saving to the central system this is no longer as attractive an offer as it was when the recording was only started once the lecturer (host) arrived. Often the lecturer joins the meeting prior to the scheduled lecture time so that the students may ask questions relating to their studies. During this time the standard video conferencing function is used to enable the lecturer and the students to engage. Two views are available in the standard mode (video conferencing), speaker view and participant view.

In screen sharing mode, the lecturer can use the Tablet PC to provide mathematical instruction as if demonstrating on a standard white board with the added benefit of the digital tools available in PDF Annotator®. In small classes students are invited to ask questions at any time. For larger classes it is recommended that the students use the 'raise hand' function. Figure 2 shows the student view when sharing the screen.

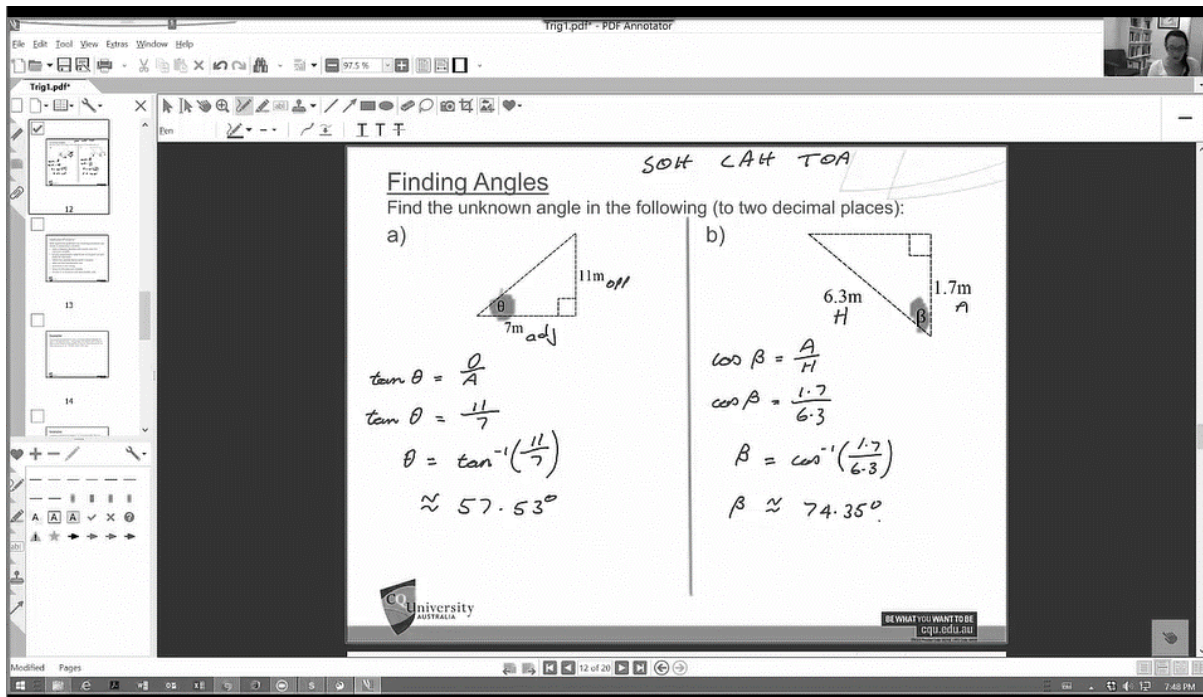


Figure 2: Student View

The full suite of annotation and drawing tools within PDF Annotator allows the lecturer to separate and point out different parts, as they explain the mathematics and method in detail. The lecturer can highlight, with different colours, important text when teaching students the development of equations from worded problems. They can use different coloured pens (or highlighters) to differentiate parts of rules or formulae, thus providing a visual map. For example, one can distinguish between the inner and outer functions in the chain rule, or between each 'u' and 'v' function when teaching the product rule, or integration by parts.

The chat function and the participant view display in separate windows while screen sharing. If many students are active in the chat it may be difficult to monitor. For large classes it may be necessary to have a support lecturer to monitor the chat leaving the lecturer to conduct their instruction. In smaller classes it may be advisable to instruct the students to open their microphone and ask questions related to the instruction if they require clarification and leave the chat for inter-student interaction. The chat may also be turned off.

Although lecture recording can be set automatically or manually at CQU all Zoom sessions are set to auto-recording. Automatic recording records from the moment the first person enters the meeting resulting in unnecessary recording before the lecture. Camtasia® can be used to edit the recording before making it available to the students. The University has automated the upload of the recordings to a video repository that sits within the Learning Management System. From here students can only see those videos associated with units they are enrolled in.

Individual tutorials and help sessions can be conducted using the same tools that are used for lectures, namely Zoom, a Tablet PC and PDF Annotator®. This is far more beneficial to students than the telephone assistance of old and has solved the problem of assisting these students 'blind'. With Zoom the student can share their screen or use their webcam as a document camera. The tutor is then able to see the students work and can assist with any misunderstandings. These

sessions are recorded and supplied to the student for their reference. In some instances, permission is sort from the student to share their recording with the rest of the class (Adams & Hayes, 2019).

Annotative Devices and their use in Engineering Mathematics Units

Foundation Mathematics (MATH11247) mathematics staff use either a Tablet PC or a Wacom monitor. The tablet PC is a notebook computer with the input function that allows the user to annotate (write) on the screen using their fingers or electronic stylus. The Wacom monitor is a touchscreen that allows annotation but it needs to be connected to PC, MAC or tablet just like any ordinary monitor. Tablet PCs are more portable than the Wacom monitor. They are lighter, efficient and affordable; processors are fast; and resolution matches any notebook. The Wacom while not allowing the portability of the Tablet PC is larger (Table 1), thus giving more real estate for writing mathematical equations. Often both the Table PC and the Wacom monitor works with an active pen that will only work with the particular product model. although handwriting recognition is still a feature in both, depending on the software installed, “digital inking” (allowing the user to annotate on the computer using a stylus or pen) proves to be its strength (Maclaren, 2014).

Klymchuk and Wilson (2019) found using the Tablet PC in the lecture helped to guide students through the content. Scaffolded content fostered the students’ developing content knowledge as they worked through the weekly schedule. Using the tablet in the lecture was integral in providing a visual step by step guide through the stages involved in solving questions. With the capacity to annotate (Table 1) the tablet has advantages over the notebook and whiteboard in a lecture theatre. Annotative devices (Tablet PC or Wacom screen), together with an LMS, can provide students with asynchronous instruction similar to a handwritten lecture.

In 2020 and 2021, due to COVID 19, all examinations were ceased. Assessment was required to be of an alternative non-supervised type that could be submitted and returned through the LMS (Moodle). For the most part this was a scanned version of the written test. This meant marking using annotative devices. Most staff come from a paper base marking system and marking on an annotative device brought many challenges and barriers.

Those staff attempting to mark on an iPad found no keyboard and written assessment to be a barrier. The lack of the keyboard could be easily overcome by using a Bluetooth® keyboard. Other challenges that staff face when marking on an annotative device include, marking quickly enough that students receive meaningful feedback in a timely manner, and ensuring that students receive full and accurate solutions to any mathematical problems that they struggled to complete correctly.

Providing meaningful feedback in a timely manner is difficult to achieve with a small screen (less than 13 inches). The small screen makes meaningful annotation on the student’s work difficult and time consuming (the annotation must be continually resized). Additionally, when a student fails to grasp a concept, the small screen makes it difficult for the academic to efficiently insert a full and correct solution. Using a larger auxiliary annotative device screen (larger than 20 inches) makes the marking process more efficient.

Staff training in effective use of annotative devices in lectures/tutorials/Zoom rooms is another issue. At CQU many of the lecture and tutorial rooms have wireless connection to the data projector using Zoom. Staff need adequate training prior to the commencement of term and easy to follow one-page guides. Adams and Hayes (2009, p. 7) found there was a one-to-one correlation between the lecturer’s perceived confidence using an annotative device and the student’s acceptance or rejection of the technology as a teaching aid.

Table 1: Summary of annotative devices used by staff from Engineering Mathematics units

Topic area	iPad (iOS)	Tablet PC (windows)	Wacom Monitor
Description	7 to 13 inch screen	10 to 16 inch screen	16 to 32 inch screen
PowerPoint presentations	Portable and can annotate on PowerPoints etc.	Portable and can annotate on PowerPoints etc.	Needs to be installed in lecture or tutorial room.
Marking assessment	Can annotate and view about third of a A4 page. Makes marking time consuming.	Can annotate and view about third of a A4 page. Makes marking time consuming.	Can annotate and view 2 A4 pages. Viewing whole page makes marking more efficient than paper based.
Portable	Light and battery last more than 7 hours.	Light and battery last more than 4 hours.	Not portable, Notebook or PC/Mac needed.
Pre-prepared material	Slides can be pre-prepared and made available before the lecture/tutorial.	Slides can be pre-prepared and made available before the lecture/tutorial.	Slides can be pre-prepared and made available before the lecture/tutorial.
Write on pre-prepared material	Slides can be written on (annotated) using fingers/stylus.	Slides can be written on (annotated) using fingers/stylus.	Slides can be written on (annotated) using fingers/stylus.
Make material available before and after the lecture	Slides can be written on using stylus and made available after with added annotations.	Slides can be written on using stylus and made available after with added annotations.	Slides can be written on using stylus and made available after with added annotations.
Videos and pictures	Students can view recorded lectures with annotated slides	Students can view recorded lectures with annotated slides	Students can view recorded lectures with annotated slides
Cost	\$600 to \$2000	\$2000 to \$5000 Additional monitor \$600 (27 inch)	\$900 to \$5000 Notebook or PC needed \$1000 to \$5000

According to Dekkers, Howard, Adams, and Martin (2013, p. 175) “the mathematics units at Central Queensland University have proven the requirement of a specific structure to facilitate ease of marking with the Tablet PC”. Despite these findings, the Tablet PC was not widely use to mark the assessment in mathematics units before COVID 19. During the pandemic, all assessment was submitted and returned through the LMS (Moodle) causing the Tablet PC to be widely adopted by academics to mark assessment. For the MATH11218 unit there can be up to 10 academics teaching and marking across five campuses plus online. To give consistent feedback to students and facilitate ease of marking, a standard handwritten digital response has been developed for each question of each assessment. The marker is then able to cut and past the solution into the student’s assessment item at the point of the error. These handwritten solutions can be edited so that only the portion of solution required (from the error) is used.

As the engineering mathematics units are delivered online, the key advantages of staff using an annotative device during COVID 19 included:

- Written (annotated) feedback provide to students using email or video conferencing (Zoom);
- The combination of both the LMS (Moodle) and tablet PC enabled academics to mark and return assessment with personalised and standard handwritten responses;
- Instructional videos with annotation were available from the unit Moodle sites which allow the students to review content;
- Using Zoom and an annotative device, academics could explain and solve questions from students online;
- Marked electronic copies of assessments allowed academics to provide further feedback to students using Zoom (or face-to-face if allowable);
- Marked electronic copies of assessment allowed for a more efficient moderation process across campuses;
- Marked assessments and instructional materials can be kept for accreditation purposes.

Academic Integrity Issues in Engineering Mathematics Units During Covid-19

In 2020 and 2021 all on-campus supervised assessment for mathematics units were replace with Take Home Exams. Student were given 24 hours to do the Take Home Exam. In this 24-hour period students need to download the assessment from the unit Moodle site, print the assessment, hand write answers/solutions in the spaces provided on the assessment, scan all pages of the assessment and finally upload and submit through the unit Moodle site.

The practice of offering the Take Home Exam was maintained over the entire year in both 2020 and 2021 for equity purposes as some students withdraw in a term and expect the same conditions of offering assessment in their next attempt. Statistics show that students have performed better with the take home exam than with the supervised exam. For example, the MATH11218 unit pass rates increased from around 56% in Term 1 2019 (supervised exam) to 69% (take home exam) in Term 1 2020.

Bretag et al. (2019) found three factors that lead to an increased risk of contract cheating: dissatisfaction with the teaching and learning environment; a perception that there are 'lots of opportunities to cheat'; and speaking a Language Other than English (LOTE) at home. Fortunately, students generally express a high degree of satisfaction with the learning and teaching environment, and the program has a relatively small number of LOTE students. However, mathematics staff have discovered their take-home examinations on various websites including Chegg, Gautmath and Symbolab.

Awdry and Ives (2020) found that domestic students are more likely to receive help from family and friends than paid sites like Chegg or online file sharing sites, and this will not be picked up by any form of technology that presently exists. Social media has also become a platform for assessment sharing. Academics devote vast amounts of time on detecting and processing contract cheating.

First year engineering mathematics has relied on discrete questions in assessments. These are easily reproduced, thereby making it easier for students to copy answers from apps such as Photomath[®] or sites such as Wolfram Alpha[®]. As apps like Photomath[®] struggle with text-based questions, mathematics take-home examinations writers ensure that these question types are included in the assessment.

Take-home examinations for engineering mathematics units have now been conducted for over 2 years. Due to the number of academic integrity issues that have occurred in the take-home examinations, the academic staff who deliver the engineering mathematics have recommended

that all engineering mathematics assessment include at least one supervised assessment. The invigilated examination would need to be conducted by the University's official Examination Centre.

Conclusion

Central Queensland University has moved forward using the LMS (Moodle) for delivery of units that enable students to submit non-supervised assessment electronically, replacing paper-based submissions. Annotative devices enable academic staff to engage online students more effectively in online lectures and tutorials and with providing handwritten feedback on electronically submitted and returned mathematics assessment. The combination of the LMS (Moodle) and annotative devices have created almost paperless courses. As this success is recognised across the University, others are incorporating it into their programs, students being the main beneficiaries of the efficiency of staff working with annotative devices. Add Zoom into the mix and students have an almost face-to-face like experience from anywhere.

Many of the initiatives introduced or perfected during COVID 19 to will continue as business as usual. One exception to this will be the take-home examinations as they have proved problematic with regards to contract cheating. It is recommended that all engineering mathematics units include at least one supervised assessment. The invigilated examination would need to be conducted by the University's official Examination Centre.

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