Online Maths Low Stake Quizzes

Faculty: Engineering
Department: Chemical Engineering
Module name: Mathematics Fundamentals/Engineering Mathematics (CENG40007, CENG50007)
Degree: Chemical Engineering
Level: Undergraduate
Academic Years: 1, 2
Format: Online
Approximate number of students: 150-160 in each year group
Delivery mode: Online
Duration: varies (as long as students need)
Weighting and credit: 10%
Module ECTS: 10.0
Module type: Compulsory

Insights colour key

Educational Developer

Inclusivity

Learning Designer

Registry

Careers

When introducing low stakes assessments with a formative function it is important to consider whether the attached credit doesn't take away from the formative focus, i.e. the focus on learning. It is important to consider the overall assessment burden for the staff as well for the students, i.e. can it be marked within the allocated time frame, can appropriate feedback be provided so that support can be put in place? These considerations should be given when designing this assessment.

Assessment overview

This is a flexible, learning focused quiz-based mathematics assessment for two maths modules in Chemical Engineering: Mathematical Fundamentals; and Engineering Mathematics. While there is a minimal amount of credit attached to the quizzes (10%) their purpose is formative, i.e. they are designed to help students learn maths concepts. Student learning is facilitated through a level of flexibility as to when to take the quiz, how long to spend on it, allowing unlimited number of attempts without any penalty and an option to work out a problem in a group.
The assessment is run 10 times throughout the academic year, covers approximately 10 questions each time and is linked to topics covered in the modules. To allow flexibility of access it is delivered online via maths aware software called WeBWork.

Although there are roughly 10 homework sets, they are made available at the beginning of autumn term (for autumn term content) and spring term (for spring term content). There are 2-3 spaced out deadlines each term. deadlines are not 10 dates but spaced out (~ 2-3 in each term). Each set covers approximately 10 questions (with some topics having more questions as more practice is required) and is linked to topics covered in the modules. The weight towards final grade is proportional to the questions. To allow flexibility of access it is delivered online via maths aware software called WeBWork.

Design decisions

Rationale for the introduction of the formative assessment

In the past one of the problems that was identified by the teaching team was that students were rarely assessed. This meant that students did not learn at regular stages across the year but rather would leave solving all the problem sheets towards the end of term with summative deadlines approaching. While in the past the students were given some problem sheets that allowed them to check their learning, those were not graded, and students would not receive any feedback on them. This meant that engagement with those exercises was unsatisfactory. Introducing regular assessment with some credit attached to it and immediate feedback was thought to eliminate this problem and improve student engagement with learning.

While there is some credit attached to the quizzes, the assessment is formative in nature as the credit is relatively small. The rationale for including this credit is to ensure that students are motivated to do the quizzes. If there was no credit attached the engagement would probably not be great, as past experience suggests.

Integrating assessment that is formative and developmental in nature but counts summatively for credit towards the degree can be a good way to encourage early, and sustained student engagement. The disadvantage is that student can perceive this as an extra, continuous pressure as these tests also 'count'. It's important to regularly reinforce that they are small

Interviewee: Vijesh Bhute
Role: Teaching Fellow; Fellow of the Higher Education Academy

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weighted and that completion of them that is more important than the mark received. This could be addressed by making them pass or fail, rather than allocating a mark. As well as pacing student learning, this approach can help to build learners' self-efficacy. This refers to an individual's belief in their capacity to achieve their goals, in this case, learning to apply unfamiliar maths concepts. Like in this example, self-efficacy can be built through creating opportunity for regular practice and feedback (either in the form of correct answers or on the problem-solving process taken). An alternative to giving credit would be to make it explicit that completing these formative assessments will help students to contribute in class and to prepare for synoptic summative assessment. This would contribute to building up the culture where the value of formative assessment is recognised without a mark attached. This could unload the marking stress and potential quality assurance complexities linked to mitigation. This culture shift, however, can take time so when attaching credit to formative assessment you need to make sure there the formative and summative assessments align.

The process of discussing approaches and solutions when doing such assessments together allows students to develop transferable skills useful in a workplace. It helps them develop negotiation skills, listen to perspectives and have a productive discussion around problems they are solving. This ability to listen to and consider other people's point of view is important for Engineering students to develop as some Imperial students can have a tendency to lack those skills. Those transferable skills can also be useful in academia at PhD level.

Giving students flexibility with when to approach the assessment and how long to spend on it helps them develop time management skills. They learn to think critically about the approaches that might work best for them and make appropriate decisions about their learning. The important thing is to make students recognise this as an opportunity at soft skill development.

There is a great level of flexibility embedded into the design. Firstly, the assessment can be done individually or as a group. The reason for allowing group work is linked to the formative nature of the assessment. Students tend to learn together and prepare for some assessments together and so is the case here. The main aim of this assessment is not to check what the students know but to encourage and facilitate learning and if that happens through engaging with others that is absolutely fine.

Giving clear encouragement for students to work on problems in groups helps to build a sense of cohort and enables students to experience first-hand, in a university setting, the value of collaborating, rather than competing. Opportunities for peer learning enables students to realise that they are not the only one who finds aspects of study difficult and that sometimes they are one who can help others with their learning. Peer interaction enables the development of emotional support for and is important for well-being.

Secondly, the assessment allows multiple attempts. In a traditional summative assessment of this type a student would have one attempt and would be informed where points were lost. Allowing multiple attempts without penalising the student aligns with the formative nature of the assessment and facilitates learning further (more on that below in the Practicalities section).

Finally, there is a level of flexibility in terms of when the student takes the assessment. There is a period of time when the quiz is open and the students are welcome to take it at any time within this period and are welcome to spend as much time of the quiz as they wish.

Giving choice around how and when students do the assessment makes it more motivating and inclusive, as they can schedule the work to suit their study preferences. If you want students to complete certain quizzes before a class, so that you can discuss their approaches, this may influence when you close them. Such deadlines may also help to signal that the goal is not to get a perfect score, but to know when to move on with the next study task.

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With such a level of flexibility embedded in the design of this assessment it is important to make sure that students fully understand the extent of that flexibility. It is important to explain that the quizzes need to be done within the time frame of the module. Current regulations also do not allow to retake modules once they've been passed in order to achieve a higher mark so it's important to put this across to students that there is a final point by which they can't simply go back and improve their score.

Rationale for electronic delivery

The exam questions are designed to be an online assessment because of the issue of universal access, i.e. to ensure that students are not disadvantaged if they cannot come onto campus and to allow more flexibility overall in terms of the time and the place they choose to take the assessment. The ease of marking, i.e. quizzes are graded automatically, also makes electronic delivery a more preferable choice.

Question design

As the software used is maths aware and recognizes equations and equivalences the questions are designed to be short answer questions, where students 'fill-in the blanks' instead of MCQs (Multiple Choice Questions). The fill-in the blank type problems implore students to think before entering collaborate, instead of randomly making a choice until they get the right the answer. If a MCQ style assessment was undertaken, students may simply keep on selecting different options until they get it right without actually knowing the concept behind their selection.

In order to make the questions more conducive to student learning the majority of questions are broken down into steps. This means that the students need to answer each step rather than the whole question. In this case it means breaking down a problem into multiple sections and that way if a student really wants the feedback on one aspect of the problem, for example their methodology, they can. This approach works well with more difficult questions but overall most of the questions are divided into a few subsections so that the answers can be checked at different stages.

It is good practice to allow students to get feedback after each section before they move on. This can help them to understand the rationale for applying concepts and reward them for effort and competence so far. It also reinforces the value of the transferable skill of breaking problems down.

The questions are aligned with learning outcomes for each of the sessions and build up the knowledge and skills tested later on and aligned with the learning outcomes of the module.

The team spent an entire summer coming up with thousands of questions collaborating closely with the students partners as part of a UROP and then Student Shapers project. The software used had a built-in library of 37000 questions that could be repurposed. The task of the students was to go through the library and select the most appropriate questions for each topic. This is how a list of tentative questions was created which was then narrowed down to the list of questions that the team deemed most appropriate. The team ensured that each topic had questions at all levels of difficulty and if that was missing from the software library, additional questions were coded by the team. The team also utilised already existing questions from a variety of textbooks or some students took the job of devising questions from scratch. The design of the new questions was as close to the learning objectives as possible and similar to the style of other questions. Problem sheets served as a template. The questions were internally validated by the team to ensure that they are correct, appropriate for the topic and the level of students and any potential errors in phrasing are eliminated.

There are 10 quizzes per year each containing roughly 10 questions. This number is thought to be appropriate as this means students are taking a quiz roughly every 2 weeks. This also aligns with how the topics in the modules are running.

Most questions have an option of providing a 'hint', which is additional information that can help students who are struggling to arrive at the correct solution.

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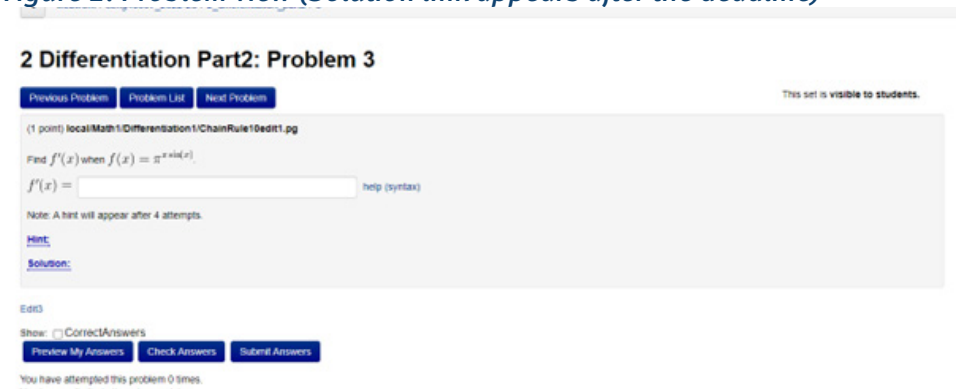
It is important to ensure that software used allows for changes to be made to the layout of the question and the exam to make it accessible to all students. In terms of the font there is often an assumption that Times New Roman is a good font to use while in reality it is really difficult for anybody with specific learning difficulties to process. In terms of the layout of the exam questions on the page, having to scroll down between the question and an answer can be challenging hence the question and answer should be visible together without the need to scroll. Another consideration needs to be given to where the buttons are placed and avoiding placing 'next' and 'submit' buttons close together as students with visual perceptual difficulties might find this challenging and accidentally click the wrong button. If a screen reader is required it is important to make sure that the text is accessible. Consider presenting multiple choice options with greater spacing between them especially if answers are very similar visually.

When planning a module level assessment diet it is important to be clear which module level ILOs are addressed by which assessments. This is going to help reduce overall assessment burden. So a mapping activity that takes into account a broader assessment view can be useful.

Figure 1: Web interface start up page

Figure 2: Problem view (Solution link appears after the deadline)



Rationale for the software used

The software was chosen for several reasons. The most important one relates to it being 'Maths aware', i.e able to read maths equations and recognise equivalences in answers. This made questions designs and input of answers easier. Secondly, the software contained a library of 3700 questions that could be reused therefore made creation of the question banks easier.

The software allows the students to preview their answer before submission which means that issues with incorrect input (such as lack of a comma or brackets) that could generate a wrong answer can be prevented.

Initially the use of Mobius was considered, however, this software was thought to have a less user-friendly interface that required a lot of coding so in the end WeBWork was chosen as the most appropriate option for what the formative feedback was trying to achieve.

Fit with other assessments and the programme/ module

This assessment fits in with other assessments on the module. For example, for The Mathematics Fundamentals module the assessment strategy consists of 80% final exam, 10% spring test and 10% is the quizzes. The questions are associated with topics covered in the two modules, to ensure comprehension of concepts. The formatives allow

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students to test their understanding topic by topic which feeds into what is assessed in the final exam albeit at a higher level. The purpose of this assessment is not so much to get the students ready for the exam in terms of practising similar types of questions but rather making sure that they understand the concepts and they can apply them in different contexts.

Practicalities

Assessment organisation and arrangements around delivery

As mentioned in the design section, there is a level of flexibility embedded into the assessment in the sense that while there are some deadlines by which assessments should be done, this deadline can be extended if necessary. The questions are randomized and personalised for each student but a level of collaboration is encouraged, not to just put the answer in but rather to collaborate on the methodology. Hence while the numbers in a question might differ from person to person, the method used to solve the problem will be the same.

The assessment that gives students flexibility in terms of the length spent on doing the quiz is designed with Universal Design in mind. Hence the spirit of collaboration and the focus on learning is a much more inclusive alternative to traditional tests that are more strictly monitored.

Weighting attached to each question is relatively small so if a student wants to, they can skip a problematic question and move on to the next. However, it is not uncommon for some students to try several times despite the low weighting. This links to the nature of the students wanting to learn and get the answer right. However they are more likely to ask for help rather than attempt an answer inordinate number of times.

Assessments are spread out throughout the term so when a topic ends students are given a deadline to complete the quizzes. There is usually a good amount of time between when the quiz opens and when the deadline for completion is set. This is to give the students maximum flexibility and help them fit this assessment around other commitments. Students are given clear indication via different channels about when a quiz opens and closes – i.e. this is communicated via Blackboard, during the teaching. Those students who miss the deadline are emailed by the tutor to clarify what the problem is.

One thing to consider when giving that level of flexibility with an assessment that is actually weighted and contributes to the final grade is mitigation. Even with such a small assessment weighting overall, if a quiz contributes to the final grade extensions should be granted due to legitimate mitigating circumstances. What to be mindful of is having too many assessment points that cause problems for students who have mitigation. So a consideration needs to be given to the value of those assessments versus the impact they might have.

If a student is struggling and would appreciate some support, the software has an option of 'email the teacher button' which notifies the tutor that the student would appreciate help. What this triggers is for the tutor to see every attempt that was made. This helps the tutor figure out what the issue might be. In some rare cases it could be that the question itself might be worded in a certain way that may lead to some issues. This means that the question can be fixed quickly and the overall issue resolved. If mistakes are more conceptual, the teacher can offer support on how to come up with a solution. There are some users who use this function quite frequently, roughly 5-10% of the class size uses it at least once in the academic year. Hence at this point offering this support is manageable for the tutor.

A different approach in the past involved having half of the questions graded (referred to as homework questions) and half of them being non-credit questions (referred to as exercise questions) with the non-credit questions being slightly easier. So a student would start with the non-credit questions as these supported those who are very new to the topic and progress into the more challenging homework questions. This allowed students to start by practising without any stress. What this led to though is all of the students accessing the graded homework questions and only 30% using the exercise ones.

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This was still fine as the purpose of those was to help students who might struggle. Currently the exercise sets are available for reference without deadlines and with solutions so students can refer to them when solving homework assignments if needed. The tutor had received a lot of requests around changing deadlines for exercise sets which are non-graded so he decided to scrap the deadline component of exercise set.

Preparing students for assessment

The idea of the formative is introduced at the start of the modules so the students are aware that they will be given quizzes after each of the topics commences. There is a FAQ handout that outlines step by step what they need to do, how to log in, how to change settings, explains different features of the software and outlines the weighting of the assessments.

Once a quiz is made available there is an introduction set that the students need to go through and only then the other sets will open. This allows them to practice. This adaptive release means that students can choose this set in the order or hierarchy that you need to complete this and then you open the rest of it. It is set so that students need to complete at least 60% of the orientation set to attempt other assignments. This introduction set tells them what the platform is, how to enter answers, how to select different kind of options in terms of notations and so on.

The same platform is used for pre-sessional courses for incoming students therefore there is a level of continuity and the majority of students are actually familiar with the platform when they come to the modules.

Marking arrangements

The software can automatically grade the students' responses and output a mark. While there is some credit attached to the assessment it is unconventional because it accepts multiple attempts that students are not penalised for. The assessment allows students to go through the trial and error process with an emphasis on student learning, meaning they can try and fail and learn from those failures in a relatively safe environment that is unlikely to majorly affect their final grade.

This means that a student who gets an answer correctly the first time gets the same mark as a student who attempts to answer multiple times. This really puts the emphasis onto learning and encourages students to take risks and make mistakes.

One change that was attempted in the past was penalising the students for using the 'hint' option. This was to discourage students on relying on the hint too early in their attempt, so a 10% penalty was applied if the students used the hint option. This meant that students would first try a couple of times and only use this option as a last resort. It turned out that students didn't really want to lose any points so the hint option was rarely used.

Current setting is to show hints after 4 attempts on a problem (as can be seen in screenshot 2 above). This number is chosen somewhat heuristically based on past experience. Students usually resolve issues and get correct answers in 1-2 attempts. There is no way to track the usage of the hints link other than asking students directly. But by having hints appear after certain number of attempts (for multi-part questions, the hints will appear later for different parts), it is hoped that this would be available to those who are struggling and avoid using them straight away.

Feedback arrangements

Students receive feedback in terms of an answer being correct or incorrect and marks attached to the correct answer, to enable them to get a sense of what went well and what didn't go as well during the assessment. If an answer is correct this is where the feedback ends. If an answer is incorrect there are several other feedback strategies utilised.

For some questions the answers are a bit more personalised. What this means is that for example if an answer needs to be accurate up to four significant digits and if the student has only entered 2 then the system will tell them: "You're very close, maybe try adding a few more significant digits". In addition to that in most cases there is an option of obtaining a hint with some information that might help students arrive at a correct answer.

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For students who are really struggling, personalised feedback from the tutor can be provided as discussed in the Arrangements section. This allows the tutor to see the attempts, ask students to send through their workings, spot any immediate mistakes and offer advice on how to approach a question differently. This level of feedback is not really built into the automated system but is an additional layer that supports student learning. Additionally, the ability to work on a problem in groups/ pairs allows for peer feedback opportunities.

Finally, there are detailed step-by-step solutions provided after the deadline, so that students can see where they went wrong and what to improve in the future. Students tend to only access solutions for questions which they got incorrect.

Online adaptations

The assessment was set online from its inception and was created during the pandemic to support students better. It is still a valuable method post pandemic.

Advantages of the assessment type

- This type of regular developmental assessment, whether designed as low-weighted summative assessments with a mark or pass/fail or purely formative, encourages early and sustained student engagement. It also provides students with the practice and feedback necessary to build self-efficacy;
- Small credit attached to it incentivises students to do the assessment;
- The flexibility of the assessment is an advantage for both the staff and the students and allows for a more inclusive design;
- The flexibility with when to take the quiz and there is nothing to stop a student making multiple attempts to achieve the right answer. It would be unhelpful for a student who is very close (i.e missing a few significant figures) to be penalised. This method enables students to have a second chance and reinforces the focus on learning;
- The students can discuss and collaborate with each other, which solidifies learning. This ability to discuss also strengthens peer support;
- The hints provided within the questions provide more of a scaffold to guide the student to the right answer, which further helps to facilitate learning;
- It is helpful that the instructor can see the student view and their past attempts to understand better at what point they got stuck. This allows for better support if needed;
- Seeing past attempts also provides an instructor with the insight to suggest a student does not need to spend so long trying multiple attempts;
- Autograding is definitely an advantage as it allows the team to shift the time that would be spent marking to supporting student learning;
- Using the software also allows access to statistics about each quiz allowing the team to identify students who are not performing well consistently or not engaging as expected. These students are then contacted by the tutor to figure out what the reason for disengagement or bad performance is and how they can be supported further;
- The method of assessment is also advantageous in the sense that it provides detailed workings of the questions after the deadline, so that students can see where they went wrong and what to improve in the future. There is also the added benefit of a personalised solution if students seek help from the tutor;

Limitations of the assessment type

- There are order of magnitude limitations, which are difficult to autograde. When there is a lack of context to a student's answer, it is hard to know what the units are;
- Unfortunately, errors in questions sometimes occur but those can be eliminated with the next reiteration of the quiz so with time these will be eradicated completely;
- There is a danger that students might feel overwhelmed with the frequency of the quizzes especially when combined with other assessment deadlines. This can be daunting especially in the first year of study when the students have many assignments and deadlines. To avoid this the module lead coordinates and liaises with other instructors to make sure that deadlines do not overlap with other coursework. This is where the flexibility of when to take the quiz also plays an important part in ensuring students have enough space to approach the assessment;
- As is often the case with online platforms of this

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type, the tutor is not able to see the workings but rather sees the final answers that were put in. This makes it difficult to see where the student is struggling and that is the important piece of information if the focus of the assessment is helping students learn. This can be circumvented by including steps. This means that the students need to answer each step rather than the whole question. In this case it means breaking down a problem into multiple sections and that way if a student really wants the feedback on one aspect of the problem, for example their methodology, they can. This approach works well with more difficult questions but overall most of the question are divided into a few subsections so that the answers can be checked at different stages;

- There could be some issues with the software recognising a blank answer that requires multiple input, as it could treat it as a list where the order might or might not matter so there is some further programming that needs to go into clarifying that;
- Another thing to be careful with is when the actual numeric answers are very small - something of the order of 10 to power -34 and that happens sometimes in physical chemistry or quantum physics. In such cases the software doesn't have that tolerance, so the default tolerances may be 10 to power minus four, so it won't recognize differences in those little answers. The way to go around it is use a different unit, which would bring the number up slightly higher.

Advice for implementation

- The current frequency of tests (10 tests/academic year) is suitable because sometimes, given the intensity at which things get near the end of an academic term, it is hard for students to keep up. Hence it was deemed essential to control the spread of assessments. Taking this broader assessment view can prevent over-assessing and overloading students;
- Ensure that the assessment is suitable for the assigned problems;
- The aim of the assessment should be the acquisition of knowledge over testing, as if it is too exam-oriented, it may put unnecessary stress on students;
- It's important to regularly reinforce that they are small weighted and that learning by working through them in a time-limited way is more important than the mark received;
- It's important to keep track of students' engagement with the assessment, which can show those who are not engaging with the problems. There may be different reasons for this (such as mitigating circumstances), but often students just forget the access code or forget the deadline;
- Students could also be encouraged to talk to their personal tutor about their approach and any struggles;
- When choosing the software, assess the pros and cons in terms of pedagogical versus technological needs;
- It is always useful to draw on the wider faculty wide knowledge and experience of the Ed Tech team who can advise on the best software to suit your needs;
- Striking the right balance between offering support in the form of 'hints' and allowing students to rely too much on this support can be tricky. This can be done by only enabling a hint option after several attempts;
- Make students recognise the skills that such a flexible approach to assessment helps them develop that can be useful in a workplace – those include time management, decision making, negotiation and listening. This can be further facilitated by adding some reflective questions at the end of the quiz to trigger further thinking such as Why did you approach the quiz the way you did? How did it work? How could it work better? This is especially beneficial in cases, such as here, where a similar assessment is repeated over a period of time;
- Ensure that the way the quiz is presented on the screen takes into account inclusivity needs of students. This includes: avoiding times New Roman font that can be tricky to process, ensuring there is appropriate spacing between dense questions, ensuring that the question and all the options are visible on one page without the need to scroll, ensuring that submit and next buttons are sufficiently separated and finally making the text reader accessible if necessary;