



# Automated Mechanical Engineering problem sets

**Faculty:** Engineering  
**Department:** Mechanical Engineering  
**Module name:** MECH50010  
**Fluid Mechanics 2**  
**Degree:** Mechanical Engineering MEng  
**Level:** Year 1 and 2  
**Academic Years:** UG 1& 2; 2020 - ongoing  
**Format:** Homework sheets and Progress Tests, online  
**Approximate number of students:** 200  
**Delivery mode:** online; both remote and on-campus  
**Duration:** Autumn and spring term (formative assessment) and summer term (Summative assessment)  
**Weighting and credit:** summative assessment is 5% of the module (low stakes)  
**Module ECTS:** 5  
**Module Type:** Core

## Assessment overview

These assessments focus on automated feedback provided for mathematical, short-answer questions to problem sets for undergraduates. The assessment feedback is both [formative and summative](#). This case study focuses on the MECH50010 Fluid Mechanics 2 module in Mechanical Engineering, which has around 200 undergraduate students.

The self-study exercises consist of homework sheets set frequently throughout the autumn and spring term with accompanied feedback. These exercises do not directly ‘assess’ a learning outcome, they provide deliberate practice which is a path to reaching the learning outcome. [The summative assessment consists of ‘progress tests’ worth 5% of the 5 ECTS module \(these are “low stakes” assessments\), set at the end of the first term;](#) 95% of the module is assessed by a final exam. There are 17 formatively assessed homework sheets in total across the module, which are set weekly in autumn and spring term. Eight of these are set in autumn term (there is one week without a test, and one week with a progress test instead) and nine in spring term (with a week off for design week, and a week off at the end of term). The formative self study exercise questions include a range of types, from basic practice, to reinforcement, to extended challenges. [They are not designed to ‘test’ understanding, but rather to give students the necessary exercise to learn.](#)

There have been various iterations of the assessment from 2019/20 to present. The assessment was initially hosted on Mobius and has been on an in-house platform - Lambda feedback - since January 2022. This platform will be used to deploy formative tests with automated feedback in up to 9 modules across College (8 departments, across two faculties) from October 2022 onwards. Collaborating departments were found through networking with teaching colleagues, e.g. via a Special Interest Group (SiG) Software for Online Mathematical Questions, Teaching Fellow lunches and contacts made on the PG Cert in University Learning and Teaching (run by the College’s Educational Development Unit).

## Design decisions

### Rationale for automated marking

Student homework sheets were not marked in the past on this module, so automation allows feedback on formative assessments where previously there was none. More specifically, it automates ‘low level’ feedback that stops students getting stuck on questions, and allows them to go deeper into their homework before requiring help. The subsequent contact time with teachers is higher quality due to deeper discussions. See this [article](#) for more.

Automation for summative assessments improves staff time management at a busy time of year and increases the speed and consistency of feedback to students. In future, as content banks of questions are developed, it may reduce staff workload. There are limitations to what can be assessed

## Insights colour key

Educational Developer

Inclusivity

Learning Designer

Registry

Careers

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Role: Principal Teaching Fellow



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automatically, but this problem can be partially solved by designing questions carefully. Ultimately, however, some teachers follow a ‘hybrid’ approach where they manually mark some parts of an assessment, for example sketches, where automated marking would be difficult.

The reason for the low stakes assessment is two-fold; it is an entry point to the technology for the teacher (allowing development of the system), and it introduces students to this type of assessment and feedback without a high mark penalty if they get things wrong. The progress tests are a good vehicle for this innovation as they are summative (so students take them seriously), but the weighting is low.

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 timeframe, can appropriate feedback be provided so that support can be put in place? All of these considerations should be given when designing assessments of this kind.

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 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. 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.

### Rationale for the design of the Lambda software

Initially the assessments were hosted on Mobius platform. However, the following issues were identified:

- General user experience (student and staff)
- Restriction on programming language to program feedback (Maple only).
- Restriction on error-carried forward capability.
- Restriction on feedback capabilities - because it is ‘grading’ focussed.
- Restriction on analytics.

A bespoke, in-house platform - Lambda feedback - has been developed using an award from the College's Digital Innovation Fund, which was used to pay software engineers to complete the programming. The module co-ordinator oversaw the project and outsourced the coding work (to a consultant and, one full-time employee, and a post-doc). The algorithms that process the student responses and supply feedback are complex. Hence the automated feedback project is split into two: 1) software development to create the host platform; 2) processing of student responses to questions in terms of supplying automated feedback. Beyond the initial funding, the platform will need ongoing maintenance to ensure that the project can be sustained into the future.

The project leader is currently working with 8 academic “pioneers” from across the College who are part of the initial development team. Their feedback and evaluation of the system has helped and will continue to help refine the software, e.g. by developing new features within the platform that support different types of teaching.

The Lambda feedback software was designed to meet the needs that Mobius couldn't. In addition to that the software will soon allow the teacher to parameterise a question, so that the exact content seen by a student is unique to them and so the

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correct answer is different for each student. There are obvious issues with the integrity of remotely-delivered summative tests, so this system allows teachers to change some (or none) of the questions, which prevents students colluding on their answers. This was particularly useful when all assessments were being delivered remotely, as Timed Remote Assessments, during the Covid-19 pandemic. Teachers can choose not to create bespoke versions of any of the questions, but students won't necessarily be told that this is the case, which, again, acts to discourage collusion.

Various types of evaluation fed into the design of the system, e.g. significant user testing with students, StudentShaper projects, SOLE responses, student survey, staff survey, SSC, Ed Tech reviews. For formative assessment the system has been improved because of these evaluations. For example, this year there is a new 'flag' system on Lambda feedback to pick-up any issues that students are experiencing with the automated feedback, e.g. if they think their answer has been marked incorrectly, due to a symbol error, etc.,. For the summative progress tests although the initial staff team working on the project characterised problems well, it was difficult to improve between the first and second iteration due to staff turnover, and instability in the organisation due to COVID.

Every new software needs to undergo approval processes before it is rolled out for College use. It is useful to bear that in mind and discuss your needs and ideas with your local Ed Tech team.

## Questions design

For the self-study exercises, the same considerations were made as for any worksheet-style assessment, including, from the student perspective: the purpose of the assessment e.g. which Intended Learning Outcome is being assessed (what concept, what skill, what knowledge, what misconception?); how long will it take to complete?; How clear are the instructions for the assessment? How much interest/engagement does it generate for the student? How easy is it to navigate through the assessment, e.g. how good is the user experience?

From the staff perspective, the teacher needs to consider how to construct a question to enable generation of the formative automated feedback, so must consider the structure of the question, and any potential ambiguity in the answer, e.g. use of different symbols for mathematical concepts.

Figure 1: A screenshot of a question within a set. A correct answer has been entered.

MECH50010 Fluid Mechanics 2

ADMIN TEACHER STUDENT SIGN OUT

Modules / MECH50010 Fluid Mechanics 2 / Set 4

Problem Set 4:  
The Euler Equations

4.1 SIMPLIFYING THE EULER EQUATIONS

4.2 EULER IN CYLINDRICAL COORDINATES

4.3 PRESSURE GRADIENTS IN THE FLOW LOOP

4.4 ACCELERATING TANK

4.5 PRESSURE IN A STRAINING FLOW

4.6 ROTATING TANK (OPTIONAL)

4.7 THE BERNOULLI CONSTANT (OPTIONAL)

### 4.5 Pressure in a straining flow

Consider a straining flow as in Q2.1 and Q2.5, i.e.

$$\vec{u} = \begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} 1 + \alpha x \\ -\alpha y \end{bmatrix}$$

and assume constant, uniform density, and no body forces.

(a) (b) (c) (d) (e) (f) (g)

Considering for now only the line  $y = 0$ , show that your answer to (b) simplifies to an ODE for  $dp/dx$ .

$\frac{1}{\rho} \frac{dp}{dx} =$

Live expression preview  
Your answer was understood as  
 $-\alpha(\alpha x + 1)$

Check

Correct




  
 Skill Level

### Guidance

In this problem a flow field is given and the Euler Equations are used to derive the pressure field, initially along a line but then for the whole pressure field.

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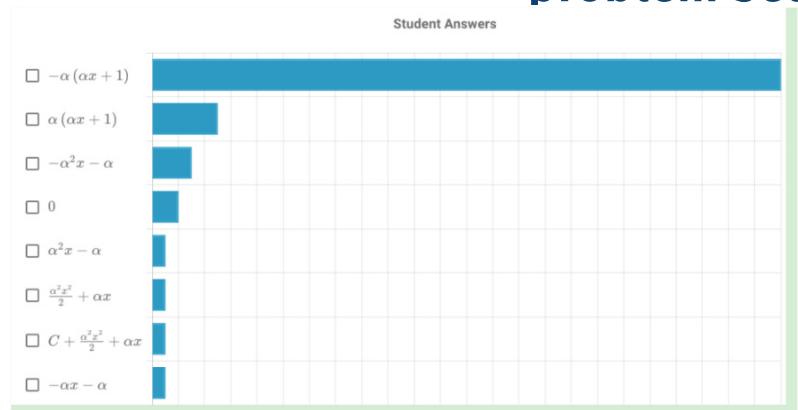


Figure 2: contextual information about the question

Figure 3: student answers, aggregated by mathematical equivalence. A sign error is the most common error. This case can be given specific feedback, as illustrated below.

$$\frac{1}{\rho} \frac{dp}{dx} = \text{a(1+ax)}$$

Live expression preview

Your answer was understood as

$$\alpha(\alpha x + 1)$$

Close. Check your definitions.

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.

For the MECH50010 Fluid Mechanics 2 module the formative assessment content is structured in a hierarchy of Sets (Sheets), questions, and parts. A question is the fundamental 'unit' of the content. Each part may or may not have a 'response area' where a student can enter a response and get instant feedback. The reason for not always having a response area is because many questions can't be automatically marked (such as "show", "derive", "sketch", etc.). Until recently feedback has been binary (right or wrong), but a new case-based feedback system has now been deployed, where teachers provide different feedback depending on different responses. The teachers will upgrade the cases as they receive data on student responses. The system has been programmed to be 'maths aware' so can distinguish, for example, between  $x+x$  and  $2x$ , but can also judge them to be mathematically equal.

For summative questions, the considerations for question design are the same, but the teacher must also consider: the clarity and conciseness of the question wording; the accuracy of the question; the quality of the question; whether or not the marking can be automated (e.g. it is not currently possible to automate marking





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for more subjective questions, such as long-answer text-based responses, sketches, etc.).

It is important to consider how the questions are displayed to make the exam inclusive. It is best to present multiple choice options with greater spacing between them especially if answers are very similar visually.

A content bank of questions has been created, which means diminishing work year-on-year by the teacher, as existing questions are easy to tweak to create new versions. Currently, the question bank runs across several modules all within the same degree programme, so there is little worry about duplication of questions (e.g. curriculum overlap) in other modules. Ultimately each module will have its own question bank.

### Fit with other assessments and the programme/module

The formative feedback assessment is new and innovative; the feedback provided does not cause any known disruption to any other module, and supports students' learning of essential concepts in a way that is beneficial to the higher level modules that they take in later years in their degrees.

For the summative assessments, changes (such as from paper based to computer based and from manually marked to automatically marked) were applied across the whole cohort to ensure consistency of the marking.

### Practicalities

#### Preparing students for assessment

As preparation for the formative assessments students are given general advice on study methods and feedback literacy. Feedback literacy is a two-way thing between students and teachers: students need to receive a lot of feedback before they get skilled at knowing how to react to it; teachers need to provide quality feedback. Students can check their understanding of the module content and concepts during bi-weekly tutorials with staff.

As preparation for the summative assessments students are given a briefing in a lecture and are given written information about it on Blackboard; they

are directed towards the ILOs, the syllabus and the module descriptor. They also take a readiness test (to check they can use the software). For one cohort (who were particularly stressed) a mock test was run too. Students are encouraged to complete the formative worksheets as preparation for the summative assessment.

Allowing some time in the curriculum to help students develop feedback literacy will greatly support students with their uptake of feedback and as a result will help them become a much more proactive and independent learners. Feedback literate students appreciate the value of feedback for their development and see it as an active process where they play an important role. They are able to process the comments emotionally by being open to critique as a way to improve. Feedback literacy can be developed through open discussion around what feedback is and how it benefits students' learning, allowing opportunities for self reflection around performance and feedback, openly discussing emotions around feedback and how to process comments to benefit learning and finally, designing assessments so that there are opportunities to apply feedback to future assignments. It is best if education around feedback literacy starts early on in the degree so that there is sufficient time for practice and so that the skills that students develop can be applied throughout the programme.

Revision isn't encouraged for the summative progress tests, as they are a spot check on understanding, and a good indicator of competency and fluency with the module content. Students take them right at the end of term, but are working on new material up until the test. They know that the test is coming, but the progress tests are deliberately unlike summer exams (which allow eight weeks of preparation, three extra revision lectures, and many drop-in clinics). Students who have reasonable adjustments in place for assessments can still have those in place for the progress test. Students are given clear guidance on how to submit their work on Blackboard.

In order to make exams inclusive allowances should be made for students with declared learning difficulties. If the purpose of the tests is monitoring progress then adding extra 25% can be overkill, however if the assessment feeds into the final mark in any way it should attract extra time. If a test is

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conducted in person this adjustment can be easily made by allowing students stay longer in the examiner hall. If assessment is automated it needs to be reprogrammed to allow extra time for specific individuals. Sometimes staff find themselves in a situation where the technology does not allow to adjust the time for specific students in which case every one should be given more time to complete. There have been many studies that found that students finish within the initially allocated time limit hence the only students that benefit from extra time are the ones who needed the adjustment in the first place.

## Monitoring student progress

After the assessment has been marked students can access the online platform and see their own answer, the result and how the question was marked. Students can access the class materials and the formative and summative assessments remotely; it is not clear if making content available online has had any impact on in-person attendance in classes, however it is known that the biggest impact on attendance is live streaming of lectures (which reduces attendance both at the live streamed lectures, and at other events on the same day). In fact, a major advantage of the frequency (and good student engagement with) the formative assessments is that they act as a form of attendance and progress monitoring.

As all the assessments are online, useful analytics can be easily generated to track student engagement, e.g. showing peaks in online activity on the day of the lecture; showing that many students access the homework sheet as soon as it is set, then engagement tails off; that there is a gradual decline in student engagement through the time, but that overall students do keep working and keep trying to catch up.

Figure 4: Problem sets (homework) 9-17 out of 17, in a module of 208 students. The colours indicate level of completion and how many students are at that level. This data was taken at the end of the academic year.

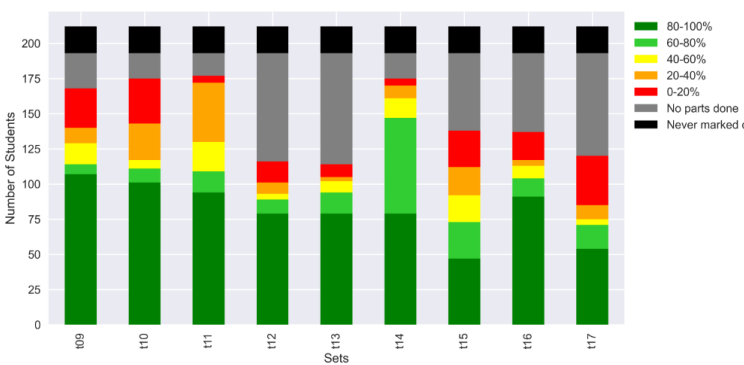


Figure 5: Temporal access to the system in one module of 208 students. Lectures were on days 18 and 25. This data is from the last two weeks of term.

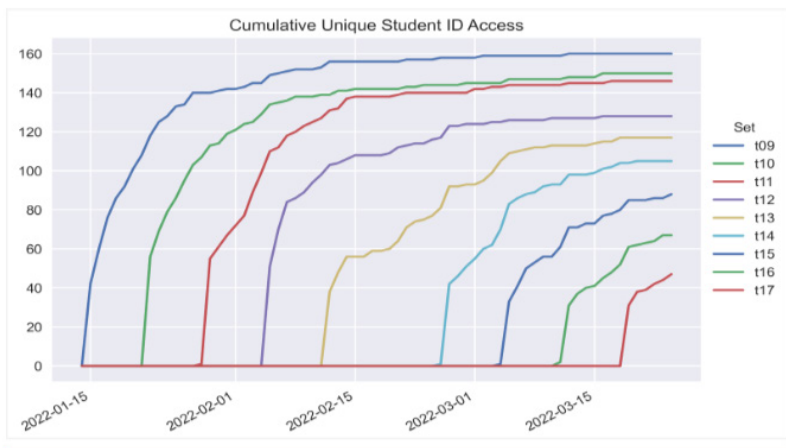
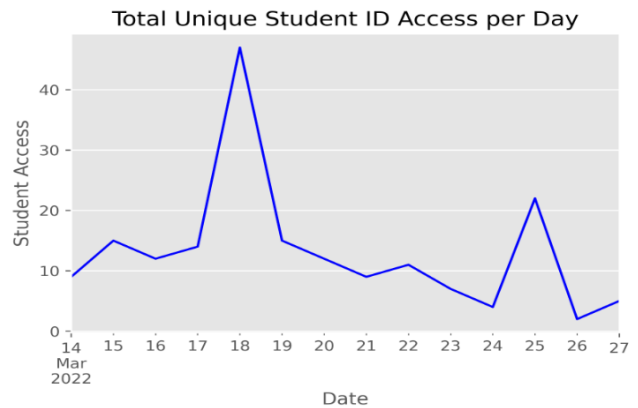


Figure 6: temporal, cumulative access for weekly problem sets. Data from the spring term. Note there is a week in the middle where the curriculum breaks for an alternative activity ('Design and Manufacture', a.k.a. 'design week').



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## Feedback arrangements

Feedback for both formative and summative assessments is automated, as discussed above in the explanation of the Lambda feedback software. It is completely consistent and objective, but also manually checked. Any changes that need to be made (e.g. if an error is spotted in a question) are applied algorithmically to the whole cohort. Feedback is delivered online, and students can ask questions about their feedback during tutorials throughout term, or in a dedicated tutorial feedback session in January, after the summative assessment has been completed. Students are given instructions on how to access their marks but aren't given additional guidance on how to make use of the feedback provided. This is appropriate for this type of low stakes assessment.

Currently, the automated formative feedback consists of "right/wrong" and to simple comments, but more sophisticated individualised feedback is being programmed and generated. There is an art to writing automated formative feedback, which teachers need to learn. For example, it might sound condescending for a computer to react to a student's wrong answer with a chirpy, "better luck next time!". There is also a potential ethics issue to consider, e.g. should an algorithm give "advice" to a student, by allowing them to progress to another part of a test before they have mastered the first part, or sending them back to an earlier assessment if they have got something wrong (this makes a lot of assumptions about a student's competency, and does not intersect well with pastoral support)? For the summative assessment the feedback is not instant, as teachers check the grading before releasing marks. Feedback is currently limited to grades (marks) with no comments.

If appropriate and pragmatic, if the only feedback is about answers being right or wrong, it is useful to offer additional commentary on exams. This can be directed at the whole cohort with a summary of common issues and an explanation where misconceptions were found. For some students, quite often international students, the main feedback events prior to university centred around correction classes where test were returned and answers were discussed in great detail. This helped students learn. The absence of such feedback contributes to their perceptions of getting insufficient amount of feedback and causing obstacles to their learning.

## Online adaptations

The summative tests were designed to be delivered online, and can be taken remotely (they are currently taken in-person, in computer rooms, but worked well entirely remotely during the pandemic). The online mode of assessment hasn't affected the design of the assessment, except that it increases the importance of parameterised questions (which are bespoke for each student) for the summative test.

## Advantages of the assessment type

- Formative feedback is entirely automated. It is consistent, objective and is manually checked.
- If any changes to the marking are required these can be applied algorithmically to the whole cohort, which saves time for the marker.
- If a student thinks that their formative feedback is incorrect, they can "flag" it on the system, which will alert the module co-ordinator, who can then go in and apply any changes if necessary.
- Formative feedback is a huge bonus for the students, as they didn't get any in the past. Students are more motivated to learn and seem happier with the feedback from the module.
- It is easy to monitor student engagement, and potentially to intervene when a student is not engaging (e.g. by alerting their personal tutor).
- The advantages to students of the automated feedback are: timeliness (the formative feedback is instant, and they can react to it and continue through their homework without getting stuck); richness and personalisation of feedback (the students answer difference questions, so receive feedback that is bespoke to them); consistency of feedback due to automation.
- Advantages to teachers of the automated feedback are: higher quality contact time, as less time is spent talking students through small mistakes in the homework sheets; insightful analytics, e.g. level of engagement and competency with the questions; improved student experience and enjoyment of the module.
- 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.

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## Limitations of the assessment type

- Summative assessment is still hosted on Mobius and for both students and teachers the user experience is poor, for example, there were a lot of browser issues with TRAs in Mobius. In terms of how the window is laid out there is a lot of poorly-used space on screen, and students have to scroll down pages to see content.
- It would be best if staff used the Mobius system directly, but they are not all trained in best practice and some are concerned about the level of support they will receive if they need help designed their assessment questions.
- Inaccurate feedback is a big problem when the marking algorithms incorrectly evaluate a student expression. For the summative assessments, once the results and answers are released students who think that their question may have been marked incorrectly are incentivised to get in touch with the module co-ordinator to query their result, because if there is an error in the feedback programming, this might result in their mark being increased. For the formative assessments, students are less likely to get in touch if they think the feedback is wrong (though the new “flag” system seeks to redress this, see advantages section).

## Advice for implementation

- Formative: it takes time to prepare content, and to refine the feedback.
- Summative: more workload upfront; new constraints on question development (restricted by what can be automated). To be most effective it requires thinking differently about the types of questions that are set for assessment, and that can be a difficult adjustment process for the teacher.
- [From employability perspective, think of ways how the development of transferable skills can be supported through preparation for the progress tests through encouraging group revision and highlighting how group revision can support development of interpersonal skills, negotiation skills and time management skills.](#)
- Ensure that the technology you choose to deliver electronic exams allows to make inclusive adjustments to the layout of individual questions and exams
- Ensure that mechanisms are put in place in terms of allowing extra time so that students with learning difficulties are not disadvantaged
- Discuss your software choices with your Faculty EdTech team
- When deciding on introducing small 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 useful to start conversation around feedback early on in the programme. Working from Year 1 on developing student feedback literacy will benefit the entire programme as students will be better able to make use of feedback throughout their degree.





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